Risø annual report 1998

Forskningscenter Risø, Roskilde

Publication date:
1999

Document Version
Publisher's PDF, also known as Version of record

Risø Annual Report 1998

Risø National Laboratory

April 1999

Risø-R-1095 (EN)

New pastures from Risø

DLF-TRIFOLIUM A/S

With support from the Danish THOR programme, DLF-Trifolium A/S and Risø have established a joint research programme to acquire the basic knowledge necessary for developing a new type of genetically engineered grasses unable to produce stems and flowers during grassland farming.

The general results will be published in the scientific journals, while results with commercial potential will be exploited within the joint venture, through commercial products and patenting. A joint research laboratory has been set up at Risø, making this project unique in Danish research.

Pictured here is the signing of the strategic collaboration agreement between DLF-Trifolium A/S and Risø in March 1998. On the left: Jørgen Kjems, Managing Director of Risø; on the right, Aksel Nissen, Managing Director of DLF-Trifolium A/S.

BOYE KOCH

From research to product

For the first time, research results from Risø have found their way into a mass consumer item. As the February 1999 advertisements on the backs of Copenhagen city buses show, what we are talking about here is a completely new type of computer mouse, FreePen, also illustrated on this page. Actually it is not a mouse but a pen, only slightly bigger than an ordinary ballpoint pen. It is not connected to the computer and needs no special mouse pad to function. Nonetheless, the tiniest movement of the pen immediately results in a cursor movement on the screen.

BILLEDHUSET / ANDERS CLAUSEN, KANITECH A/S

MICHAEL FISCHER

With FreePen the user has more possibilities than with a traditional PC mouse as it is intuitively easier to work with the pen. It minimises the user's risk of contracting the increasingly widespread IT-work related musculoskeletal disorders.

FreePen holds in its heart the first commercial incorporation of a speckle-based miniaturised optical detector system that can register rotation, speed and direction of rotation accurately. This detector system is based on a Risø patent.

FreePen has been developed in close collaboration between Kanitech A/S and Risø. Pictured here is Head of Programme Steen Grüner Hanson testing the new pen just before it went into production in the spring of 1999. He is also the inventor of the Risø patent.

BOYE KOCH

Contents

New forms of collaboration

External relations made their mark on Risø's activities in 1998. This was the main topic of the symposium to mark Risø's 40th anniversary. It is a recurring theme in the book *Til samfundets tarv – Forskningscenter Risøs historie* (Meeting society's needs – the story of Risø National Laboratory), published to commemorate the anniversary. And it plays a prominent part in the new management performance contract with the Ministry of Research and Information Technology, which came into effect on 1 January 1998, and which sets out a number of goals for the ongoing expansion of collaboration with the academic world and industry.

Risø's collaboration with universities and government research institutions is in line with Danish research strategy. It entails obligations for both parties and involves the development of more operational and integrated forms of collaboration, and its purpose is to realise the strategies of the collaborating parties and to achieve maximum synergy between their respective competences.

This applies to the agreements that Risø entered into in 1998 with The National Environmental Research Institute (DMU) and negotiated with the Technical University of Denmark (DTU) and the Danish Institute of Agricultural Sciences (DJF)

The agreement with DJF fits within the framework of the national agricultural research strategy. It covers the areas where the two institutions have common interests. Beyond this, it defines the three specific strategic areas of collaboration for which common goals are being set.

The agreement with DMU means that the activities of the DMU Systems Analysis Department and Risø's research programme Energy Systems Analysis are being integrated into a new Centre for Analysis of the Environment, Economy and Society, whereby the two institutions will co-ordinate their efforts in this area, sharing tasks, finance and management.

Risø and DTU have agreed to enter into three agreements under the national strategy on materials research. This means that a new joint centre for polymer research and two joint programmes, one for materials research on the nanometre and micrometre scales, the other for biomedical optics are being set up. The agreements cover an exchange of staff, whereby Risø becomes involved in teaching at DTU and DTU becomes involved in Risø's research.

The agreements with DTU have the character of a strategic alliance that could provide a model for entering into agreements with other universities for exchanging services in the form of research and teaching, as well as the operation of major research facilities and management of major strategic research projects.

The THOR projects that Risø entered into during 1998 with Danfoss A/S and DLF-Trifolium show that a similarly integrated type of collaboration can be established with industry. The agreement with Danfoss A/S concerns the development of artificial muscles, while the agreement with DLF-Trifolium concerns the development of knowledge to make it possible to control the formation of stems and flowers in grasses. This work is located in Risø's Department of Plant Biology and Biogeochemistry as an independent programme, DLF-Risø Biotechnology, and is managed by a researcher employed by DLF-Trifolium. In other words, this is a form of collaboration in which the boundary between publicly and privately funded research has dissolved.

The same is the case in the venture with Kanitech A/S for the development of the brand new FreePen, discussed in detail elsewhere in this annual report. Here, Risø has taken part in a development process, involving one of its own patents, together with a private company.

Another element in this development is Risø's participation, through CAT, in Universitets Innovation A/S, which includes the science parks and the universities in the Greater Copenhagen area. Its purpose is to facilitate industrial access to and commercial utilisation of the knowledge and competence of the institutions concerned. In that connection, it should also be mentioned that in 1998, Risø – on its own or jointly with collaboration partners – has applied for eight patents and entered into seven new licensing agreements on the use of patents and know-how.

Thus, Risø's activities are increasingly being of direct use to society, creating new knowledge that benefits the authorities and the education system and being of value for Danish companies.

The activities in 1998 were a good start towards fulfilling the new management performance contract, and the orientation towards the educational and industrial community was further strengthened with the appointment of Jørgen Honoré as deputy director.

Risø increased its income in 1998, thus maintaining the positive trend of previous years. A modest increase in expenditure levels on wages and operating costs contributed to an operating result considerably ahead of budget. This will ease the financing of needed investments, including the construction of the planned wind energy centre. This year again, there is reason to emphasise the major effort underlying the growth in activities and income, and to thank Risø's staff warmly for their excellent achievement.

Ulrik V. Lassen
Chairman of the Board

Jørgen Kjems
Managing Director

Results count

BOYE KOCH

Risø has entered into a strategic venture with Torsana A/S, primarily on biomedical optics. Pictured here is the company's Managing Director Steen Juel Nielsen (right) together with two of Torsana's own researchers, Rocio Chongtay, Ph.D., and Ulrik Skands, Ph.D.

The international community has an increasing need for greater efficiency and more knowledge-based production. The research content of products and processes is on the increase, and that sharpens the requirements for the applicability of research at Risø. We need to put the research we produce to good use. The next four pages highlight a number of projects and initiatives we have had reason to be proud of in this connection during the past year.

Research in its working clothes

Kanitech A/S

The launch of FreePen at the beginning of 1999 is a good example of Risø's close contacts with Danish industry. The pen is a result of collaboration with Kanitech A/S. This illustrates the fact that our strategic focus on miniaturised, laser-based measuring systems has created new technological development opportunities for Danish industry.

FreePen is a little larger than an ordinary ballpoint pen and represents an alternative to the computer mouse. The pen contains a radio link with the PC. The rotation and direction of rotation of the ball are sensed by a laser measuring system and translated into digital signals that control the cursor on the screen. The principle is based on a Risø patent relating to non-contact measurement of rotational speed. This is the first time the patent has found an application that involves an inexpensive, mass-market consumer product.

DLF-Trifolium

In 1998 DLF-Trifolium A/S and Risø National Laboratory signed a contract on strategic collaboration for the purpose of developing a completely new generation of grass varieties unable to produce stems and flowers during grassland farming. The novel grass will have increased fodder value and will thus be particularly useful in animal feed production for cattle farming. In addition to this, the programme will provide novel technologies for the biological encapsulation of genetically engineered crops, whereby spread of active transgenes in nature is avoided. The joint venture runs for four years. The general results will be published in the scientific press, and commercially valuable results will be exploited jointly by the partners through commercial products and patenting. A joint research laboratory has been established at Risø, making the project unique in Danish research. The THOR programme (Technology by Highly Oriented Research) of the Danish Research Councils supports the project with funding amounting to almost DKK 10 mill. Additional significant investments in the project come from both DLF-Trifolium A/S and Risø National Laboratory. Total investment in the project will amount to approximately DKK 40 mill.

Torsana A/S

Risø has entered into strategic collaboration with Torsana A/S, primarily on biomedical diagnostics. So far, eight areas have been identified where Torsana sees commercial potential resulting from Risø's research. Torsana has an option on the rights to the projects, so the company can decide what it wants to proceed with. Torsana is already continuing projects in two areas. One is an extremely sensitive measuring principle with biomedical applications. The method is based on the measurement being taken inside a laser. The degree of sensitivity thereby achieved is many orders of magnitude better than methods used previously. Verification of the method is taking place in conjunction with Torsana Diagnostics Biosensor A/S, Giga A/S, Ionas A/S and Mikroelektronik Centret. The other project involves a so-called phase-conju-

In April 1998, the leading scientific journal Nature's front cover was based on an article on magnetic flux-line lattices in superconductive ceramics, written by Risø researchers in collaboration with colleagues from Lucent Technology, USA. Two of the Risø researchers are shown here, Morten Ring Eskildsen (left) and Kell Mortensen.

BOYE KOCH

gate laser. This makes it possible to synchronise an array of small, low-cost semiconductor lasers, thus producing relatively inexpensive high-power, high-quality laser light. The laser will be used in materials processing as well as in medical diagnostics and therapy.

Fingerprinting ornamental plants
Risø has analysed twelve different types of Kalanchoë for a private firm. The purpose was to find genetic markers or "fingerprints" to make it easy to distinguish different types from one another during the breeding process and in production. The results demonstrate that DNA markers may be used as "genetic fingerprints" for genotype differentiation.

Knowledge capital growing steadily
The year resulted in a number of new patent applications and "seeds of ideas" for new products and new activities alike. At the same time, it is gratifying to note that this success has not impinged on knowledge production measured in terms of the number of publications appearing in international journals. On the contrary: particularly for the Optics and sensor systems programme area, there was a major increase in 1998 over 1997. Risø as a whole also showed gratifying success.

Overview of patent applications submitted in 1998

Title/application	*Application number/inventors*
High Temperature Sealing Materials Sealing materials for use in the operation of fuel cells at high temperatures	60/112039. Submitted in the USA. Applicant: Haldor Topsøe A/S. Carsten Bagger, Peter Halvor Larsen, Jørgen Gutzon Larsen
Additive for SOFC Components New combination of ceramic plates for fuel cells, which improve their yield capacity	Danish patent application no. PA 1998 01497. Søren Primdahl, Carsten Bagger, Mette Juhl Jørgensen, Mogens Mogensen
Prolin-based DNO Structures New type of molecule for optical data storage	Danish patent application PA 1998 00855. Palle Hedengren Rasmussen, P. S. Ramanujam, Søren Hvilsted, Rolf Henrik Berg
An Optical Image Encryption/Decryption Method and System New, more secure method of encoding in connection with access codes	Danish patent application PA 1998 00869. Jesper Glückstad
N-Tuple or RAM Based Neural Network Classification System and Method New, faster and more secure method for training machines	PA 1998 00883. Christian Linneberg, Thomas Martini Jørgensen
A Process for Solubilising Hemicellulose New process for breaking down plant matter ready for further industrial processing	PA 1998 01133. Co-applicant Bio Crack ApS. Anne Belinda Thomsen, Jens Østergaard Jensen, Bio Crack ApS
A Method and an Apparatus for Severing or Damaging Unwanted Plants New method of weed control	Danish patent application no. PA 1998 00953. Co-applicant Danish Institute of Agricultural Sciences. Jørgen Schou, Torben Heisel, Danish Institute of Agricultural Sciences
Flexible Rotor New type of hub for wind turbine rotors giving greater flexibility and requiring less in terms of material	Danish patent application no PA 1998 00721. Flemming Rasmussen, Per Vølund, Jørgen Thirstrup Petersen, Bjørn S. Johansen Preben Ellebæk

BOYE KOCH

Among Risø's patent portfolio is a patent for optical storage, which can be used inter alia on holographic smart cards, e.g. "intelligent" credit cards. The illustration shows a reconstruction using a HeNe laser of a hologram stored on 1mm^2 of a DNO film, which is an optical data storage material.

MICHAEL FISCHER

Risø places great emphasis on contributing to the education of young scientists through graduate studies, Ph.D. and post doctoral programmes, along with involvement in graduate schools. Shown here is Ph.D. student Helene Klinke, an employee in the Department of Plant Biology and Biogeochemistry, where she works on the identification of potential fermentation inhibitors in wet-oxidised straw.

Apart from those listed, a number of patent applications have been submitted by external collaboration partners in connection with commercial projects.

Results count

NORDFOTO/OSAMU HONDA

The signing of the Kyoto Protocol has focused international attention on the reduction of greenhouse gas emissions. This has led to a number of new assignments for the UNEP Centre at Risø. The Centre enjoys a leading international position in methods of analysing emission reduction strategies and has just published a new report series, "Guidelines for national mitigation analysis". Pictured here, at the signing of the Kyoto Protocol, are John Prescott, UK Environment Minister, together with EU Commissioner Ritt Bjerregaard.

Strength and flexibility are quite considerably increased in a new type of fuel cell developed by Risø. This means that the cell will adapt easily to a stack resulting in a longer life and a higher performance. At the same time, the operating temperature has been reduced, thus taking the technology a major step towards commercialisation.

BØYE KOCH

Risø's core competences strengthened

The basis of ongoing innovative support to industry is the continual expansion of Risø's core competences, which is achieved by means of long-term research, financed by means of Budgetary Act as well as Danish, European and international research programmes. Some particularly notable examples which contribute significantly to cementing the high level of skill in Risø's core competences are highlighted here.

Three-dimensional close-ups of the structure of materials

A new X-ray spectrometer for materials research, capable of performing 3-D studies of materials with high-energy X-ray diffraction, has been designed at Risø and is now being commissioned at the European Synchrotron Radiation Facility in Grenoble, ESRF. The spectrometer has been constructed at Risø, and research work will commence in early 1999, including collaboration with universities and industry in the UK and Germany in addition to Risø and ESRF.

Promising SOFC fuel cells results

With support from the EFP programme, Risø is developing high-efficiency fuel cells for the generation of power and heat from hydrogen or natural gas. A new type of cell was developed in 1998; its operating temperature has been reduced from 1000°C to 850°C. This allows the production of much cheaper cells; a major step towards commercial application. The project is being carried out in collaboration with Haldor Topsøe A/S, IRD A/S, OU and DTU.

Breakthrough in understanding superconductivity

In April 1998, the cover story of the leading scientific journal Nature was based on an article written by Risø researchers in collaboration with Lucent Technology. The article describes the characteristics of magnetic flux lattices in the superconductive material $TmNi_2B_2C$ investigated by neutron scattering at DR3. In moderate-strength fields, an external magnetic field penetrates the superconductor in insulated areas, forming a so-called magnetic flux lattice, which co-exists with the superconductivity properties. In stronger fields, which are also formed by strong currents in the superconductor, the magnetic field prevails. Its behaviour is uncontrollable and it negates the superconductivity. Thus, this basic research is highly relevant to ongoing work on the development of superconductor cables which, for practical applications, must be capable of withstanding high intensities of current.

New advanced laboratory for surface characterisation

A new laboratory has been set up in the area of surface characterisation to study surface effects. One of the key strengths of the laboratory is in the area of polymers. The instrumentation is coming together and, on the industrial side, there are high expectations of the potential of this advanced set of instruments.

Fusion plasmas with perspectives

Measurements carried out in a major fusion experiment at the Max-Planck-Institut für Plasmaphysik have demonstrated a clear link between plasma confinement and intensity of turbulence. Researchers have recently observed that the transport of coherent structures in the plasma is dependent upon dynamic effects in totally different directions than was believed hitherto. These results are of major importance to research into fusion energy and may find applications in other contexts. For example, as discussed later in this report, some of the measuring techniques employed have formed the basis for constructing a new control system for wind turbines; a patent is pending for this.

Shortcuts to healthier plants

Powdery mildew attacks on barley constitute one of the greatest problems in plant breeding, and work is in progress to facilitate rapid, targeted development of resistant plants. Risø has succeeded in incorporating a particular molecule into the mildew by means of genetic modification, making it possible to detect the very early phases of mildew attack on a plant cell. This technique will facilitate and accelerate the development of biologically resistant strains of grain.

Shortcuts to reduced use of plant fertiliser

Micro-organisms can supply plants with a number of different nutrients. The exchange of nutrients between plants

and micro-organisms may be exploited where plant breeding is based less on the addition of commercial fertiliser. This is the subject of research at the new Plant-Microbe Basic Research Centre opened at Risø in 1998 with brand new, advanced laboratory facilities, with support from the Danish National Research Foundation.

Danish centre for human–machine interaction

In 1998, a contract was signed with the Danish National Research Foundation concerning the establishment of a Danish centre for human–machine interaction. Risø is host to the centre, which has been established in close collaboration with AAU. Other participants are DTU, DMI, and Danfoss A/S. The centre was opened on 28 October 1998.

Follow-up on climate conference

The UNEP Centre reported on a significant international project at the climate conference in Buenos Aires. The project gives the methodological basis for calculation of costs in the reduction of greenhouse gases and adjustment to changes in climate. The report forms part of the international standard in the field and has served to strengthen the leading international position of the UNEP Centre.

Virtual wind tunnel facilitates wind turbine development

Excellent progress has been made in the development of the so-called numerical wind tunnel for calculating loads and stability resulting from the interaction between air flow and the deflection of the blades on a wind turbine rotor. The application of these types of calculations has – in the words of the manufacturer – been crucial to the development of the new 2 MW BONUS wind turbine.

Modelling of stable boundary layers

Climate models, weather forecasts and models of the greenhouse effect all make use of models of the atmospheric boundary layer. In an European joint venture, the so-called Monin-Obukhov scaling model was expanded to cover stable boundary layers which frequently occur at night.

BOYE KOCH

A licensing agreement has been entered into with Ibsen Micro Structures A/S on a joint patent with Risø for a laser-based system for precise measurement of angles of rotation. Pictured here is one of the inventors, Husain Imam. In the background, a picture can be seen of the grainy structure, called "speckles", that occurs when laser light is diffused from a rough surface and is used to determine the motion of the item.

Reconstruction of doses from nuclear accidents

Optically stimulated luminescence (OSL) in natural materials containing quartz or feldspar has been developed for retrospective dosimetry, i.e. reconstruction of the dose received by the population in the wake of nuclear accidents. Two powerful new OSL stimulation units have been developed, giving improved sensitivity. The method makes it possible to analyse individual grains of quartz in samples collected from an accident zone. The apparatus has been supplied to a number of laboratories in the USA, Australia, Japan, the UK and Germany on a commercial basis.

Researcher exchange and education of scientists

Two graduate schools have been established in the areas of bio-physics and non-linear dynamics.

The EU-financed TMR programme gives European scientists access to the Risø neutron scattering facilities at DR3. Following a particularly positive evaluation in 1998, the programme has been renewed until March 2000.

List of licensing agreements entered into in 1998

Invention	*Company*
Laser-based measurement of rotation	Kanitech A/S
Optical storage	Optilink AB
Holographic smart card	Optilink AB
Intracavity affinity sensor	Torsana A/S
A method for enhancement of the coherence properties of laser systems using phase conjugate feedback	Torsana A/S
Procedure and apparatus for determining angle deflection	Ibsen Micro Structures A/S Joint patent
N-Tuple or RAM-based neural network classification system and method	Intellix A/S

Industrial materials

MICHAEL FISCHER

Ph.D. student Søren F. Nielsen is employed in the Materials Research Department, where he works on the structure of deformed metals studied using synchrotron radiation, for example.

New materials are essential for improvements in current technology and lead to improved resource utilisation, reduced environmental impact and increased Danish competitiveness in the areas of energy technology, industrial processes and products. Risø's industrial materials programme contributes to Danish society by opening up new opportunities through basic and applied materials research. In addition, the programme contributes to a strengthening of university teaching in materials physics, chemistry, mechanics and technology.

The results of research from the industrial materials programme are widely applied within the teaching and industrial sectors, particularly in the energy and transportation sectors.

Tasks funded directly by industry

A number of tasks are funded directly by industry and are often of a confidential nature. Notable examples include advanced materials testing – destructive and non-destructive – also linked to life-expectancy calculations, design and manufacturing of light components from fiber composite materials, and the development of materials and processing techniques for new types of sensors.

Danfoss A/S

Many years of collaboration with Danfoss A/S on the analysis of material properties under dynamic loading has led to a significant improvement in the durability of press tools, e.g. used in cold forging and the manufacture of synthetic diamonds under high pressure conditions.

Industrial collaboration supported by the Danish Agency for Trade and Industry

Major industrial problems are often addressed in research programmes with industry, research institutes and universities participating. Examples of programmes supported by the Danish Agency for Trade and Industry are the development of new powder metallurgy methods as an EUREKA project, and the production of steel alloys by means of spray forming, under a centre contract with the DTI and a number of industrial companies. It is now possible to produce steel blanks weighing up to approx. 10 kg.

BOYE KOCH

Process development and optimisation of autoclave consolidation for manufacturing of parabolic antenna shells. The task was commissioned by Saab Ericsson Space AB, Sweden.

BOYE KOCH

Risø's fuel cells were nominated for the annual Patentpris award 1998. The photograph shows two of the inventors, Carsten Bagger (extreme left) and Mogens Mogensen (second from left) together with Søren Primdahl, Mette Juhl Jørgensen and Olga Marina (seated), who participated in the project.

Industrial collaboration through the EFP programmes

Other joint projects with Danish industry have been supported by the Danish Energy Agency, the fuel cells project discussed on the introductory pages being one example. Another significant project is the design and manufacture of a light, strong flywheel for energy storage in collaboration with TERMA Industries A/S, DEMEX A/S and NESA A/S. The flywheel has been tested at rotational velocities up to 18,000 rpm.

Broad-based EU-supported joint ventures with industry

Broad-based collaborative ventures with European industry are being implemented through the BRITE-EURAM and JOULE-THERMIE programmes of the EU. Examples are improved forming processing in the aluminium industry; advanced casting and forging processes designed to improve product characteristics; reduced wastage of materials and cleaner manufacturing processes; non-destructive methods and equipment for rapid, precision control affording improved safety and economy in the energy and transport sectors, and finally, fuel cell research focusing on durability and reducing the cost of cells and cell stacks. See the introductory pages.

Long-term research is the basis of development and demonstration projects

The development and demonstration projects of this programme are underpinned by long-term research. One example is collaboration with the DTU about modelling of materials processes at the atomic level, which is being extended to include dislocation processes and structures undergoing plastic deformation and heat treatment. Thus, the research ranges from the nanometre scale to the micrometre scale, and the programme forms the basis of formalised collaboration on materials physics between the department and the DTU. This collaboration extends the department's collaboration with Danish universities, which has also included collabora-

tion with AAU on composite materials, collaboration with OU on electro-ceramics and with DTU and AAU on materials processes, characteristics and modelling. The latter takes place within the context of MP2M, an MUP2 programme. Collaboration with ESRF is discussed in the introductory pages.

The Engineering Science Centre

Aside from university collaboration, materials research during 1998 has also been carried out within the framework of the Engineering Science Centre on materials structures and materials models. Here, significant progress has been linked to the study and modelling of the behaviour of materials under dynamic loads and the measurement and modelling of internal stresses in metallic constructions, welds being one example.

Other research has concentrated on the material structure and characteristics of metals which have been plastically deformed and perhaps heat-treated. An important result from 1998 is the demonstration of the link between the crystal structure of a metal and its microstructure. This result forms the basis for formulation of materials models in which the development of materials properties, e.g. directional properties (anisotropy), may be correlated with the conditions under which a material is formed.

From materials research to product development

Work in 1998 has illustrated the important connection between materials research and product development, where significant progress is linked to new materials and manufacturing processes as well as to the development of materials and technology in commom use. In addition, there is ongoing development of quantitative methods of characterisation from microscale to product level. The long term aim is development of materials and products with improved characteristics and better durability, produced by using eco-friendly processes.

The fusion programme

In the European fusion programme, relatively short-term work is being undertaken on radiation in the DR3 reactor, along with studies of alloys (e.g. based on copper or molybdenum) and welds for use in ITER. In the longer term, in-depth studies are being carried out in connection with the development of new types of materials capable of withstanding high thermal and mechanical loads in the core of a fusion reactor without becoming strongly activated. The aim is to reduce environmental impact by reducing radioactive waste.

Education of scientists

During 1998, university collaboration also included increased teaching activities, e.g. in the fields of dislocation theory, electron microscopy and defect chemistry at DTU. Furthermore a distance-learning course on new materials has been given in collaboration with AU and AAU; upper secondary-school teachers and pupils are taught about polymers, polymer composites and materials physics. A new initiative is the engagement of engineering students to carry out relevant industrial assignments in close collaboration with an industrial company. Five DTU students took advantage of this opportunity in 1998. The participating companies are existing collaboration partners of the department.

MICHAEL FISCHER

Risø is working on the design and manufacturing of a light but strong flywheel for energy storage purposes in a venture with TERMA Industries A/S, DEMEX A/S and NESA A/S. The vacuum containment is shown in the foreground, and in the background is seen senior researcher Svend Ib Andersen (right) and research technician Jens Olsson, from the Materials Research Department with the flywheel rotor.

In 1998, research collaboration with universities was supplemented with collaboration on organisation of the 19th Risø Symposium on Materials Research, entitled "Modelling of Structure and Mechanics of Materials from Microscale to Product", with some 80 delegates representing industry and research interests from approx. 20 countries.

The industrial materials programme is based in the Materials Research Department.

In 1998, the department engaged 103 man-years, 14 of which involved Ph.D. students and post docs. The department's financial turnover was DKK 68.7 million, 34.8 million of which was derived from research contracts.

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New functional materials

Several patents in Risø's portfolio concern the manufacture and preparation of polymers. The picture shows Risø's new mixing extruder, used partly in the production of well-defined polymer mixtures and partly for extruding plastic in various geometries. Pictured is post doc Henrich Frielinghaus.

BOYE KOCH

Through its research, the programme aims to improve existing materials used in industry such as bulk polymers and to create new high-technology products through working with completely new types of materials, e.g. actuators. The link between the atomic and molecular composition of materials and their fundamental characteristics is determined by combining structural characterisation and modelling with design and synthesis, as well as by function testing. The research also includes the physics of biological systems, which may pave the way for new biotechnological products.

Interaction with industry

The lion's share of collaboration with industry in this programme takes the form of research supported by public funds. A number of tasks are, however, carried out on a commercial basis or through bilateral agreements, where post docs are directly sponsored by industry.

Danfoss A/S

The "ARTMUS" project with Danfoss A/S and DTU began in 1998. Artificial polymer muscles are being developed in the project. They can function as precision mechanics movement apparatus such as valves or gripping hands in robots. The project runs in parallel with a project on miniaturised versions of artificial muscles, supported by the STVF.

Novo Nordisk A/S

Studies are being carried out into the surfaces of materials for use in medicine containers in collaboration with Novo Nordisk A/S. This work has resulted in a number of patent applications.

Analysis equipment and scientific expertise is being utilised in a number of minor contracts.

Topsil A/S

In collaboration with Topsil A/S and Mikroelektronic Centret, the characteristics of silicium bicrystals are being studied for use in semiconductor components. Possible patenting is being considered.

Mallinckrodt Ltd

Compounds for special radioactively tagged chemicals are being produced for Mallinckroth Ltd in the Netherlands.

Instruments and consultancy

Instruments are being developed and sold, in some cases in collaboration with an industrial partner. Expertise in neutron instruments has led to membership of the "Instrumental oversight committee for the US National spallation neutron source", and to employees being engaged in consultancy activities in Indonesia, Taiwan, Korea and Europe's major neutron and X-ray synchrotron radiation facilities.

Industrial collaboration through research programmes and establishment of centres

The programme participates in European programme research contracts in the areas of basic research and industrial development.

Philips

Led by Philips in the Netherlands, work is being done on "plastic transistors" under an EU development programme. The purpose is to study the possibilities for replacing some of the layers in traditional silicium transistors with polymer layers. Risø's part in the project is to study how such plastic materials can be constructed, together with documenting the manufacturing processes and materials parameters.

Danish Polymer Centre

The contract with the Danish Polymer Centre expired in 1998 after a four-year period. The scientific results achieved by the centre over these four years and through the associated MUP2 contracts have led to a strong desire on the part of industry and the Ministry of Research and Information Technology for the activities of the centre to continue. A proposal is currently being negotiated to this end. The Danish Polymer Centre has housed industrial collaboration projects and numerous basic research activities alike.

Industrial collaboration with some of the centre's partners in industry, Novo Nordisk A/S, Coloplast A/S and others is continuing through bilateral agreements or with sponsorships from national programmes. The collaboration has resulted in a number of patent applications. A patent is also pending for peptide-based optical storage materials.

Haldor Topsøe A/S and NST

The DANSYNC project gives Danish users access to the synchrotron sources at HASYLAB, Hamburg, and ESRF, Grenoble. The project has led to an industrial post-doctoral project to investigate the microscopic structure of aluminium catalysts in collaboration with Haldor Topsøe A/S. Projects on the development of superconductor cables for industrial use are being carried out in conjunction with Haldor Topsøe A/S and NST.

Development of key competences

It is a matter of great importance to the plastics industry to expand knowledge of polymer phase diagrams, since phase diagrams make it possible to improve processes for the manufacture and preparation of specific-purpose plastics. Thus, long-range, broad-based basic research work is being conducted with a view to building up expertise in this area. To highlight but one significant result out of many in 1998: in crystallographic studies of a so-called gyroid phase in block co-polymers subjected to lateral movement, a completely new phase has been identified, a so-called two-dimensional powder.

Another key area is the building up of extensive expertise in the manufacture of bowl-shaped molecules, known as calixarenes. This makes it possible to manufacture sensors that work by molecular recognition.

Neutron spectrometers at DR3

The largest experimental facilities of the Department are the neutron spectrometers at DR3. Researchers from the Department and from the Materials Research Department conduct experiments aimed at elucidating the structure of condensed matter with a view to relate structural properties to mechanical electronic and magnetic properties of materials. Both fundamental and technologically important properties are investigated.

The international standing of the facilities is illustrated by the fact that the EC finances the access of European researchers to the spectrometers at DR3 to perform experiments in collaboration with Risø researchers. The instrumentation is developed in order to make the facilities more user friendly in a manner that will strengthen the potential for collaboration on a future European spallation neutron source.

Instrumentation for surface analysis

The Department is building a broad line of surface characterisation techniques. Besides X-ray and neutron scattering techniques, topological and chemical characterisation techniques are available. A new facility for advanced surface mass spectrometry (TOF-SIMS) will be operational in early 1999.

Teaching and educational activities

A bio-physics graduate school has been established in collaboration with the Niels Bohr Institute at KU and the Danish Research Academy. Groups from DTU and KVL, are also participating. A Ph.D. course in advanced magnetism has been offered jointly with the Niels Bohr Institute and DTU. The scientists have taught at a number of summer schools for young scientists.

BOYE KOCH

Risø has expertise in the production of special chemical compounds in large quantities on a commercial basis. Pictured here is Risø's pilot plant unit, used in the synthesis of special materials in conformity with GMP regulations (Good Manufacturing Practice) for Mallinckrodt Medical in the Netherlands, among others. Pictured are laboratory head Ole Jørgensen and laboratory technician Helle D. Rasmussen.

Special studies

In 1998, the New Functional Materials programme was host to seven special students. The University of Copenhagen has made use of an external lectureship and a major experimental course in neutron scattering has been implemented.

Advanced polymer course for industry

The Danish Polymer Centre ran a course in advanced polymer science for industry in 1998.

The programme for new functional materials is based in the Condensed Matter Physics and Chemistry Department.

In 1998, the department engaged 69 man-years, 22 of which involved Ph.D. students and post docs. The department's financial turnover was DKK 52.4 million, 21.4 million of which was derived from research contracts.

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Optics and sensor systems

BOYE KOCH

Risø has a joint patent pending with the Danish Institute of Agricultural Sciences for a new method of weed control. Pictured here are senior scientist Jørgen Schou (right) and research technician Arne Nordskov of the Optics and Fluid Dynamics Department.

Industry's need for new types of miniaturised optic systems for measurement, information storage and energy-effective image and pattern generation provides the basis for Risø's research in optics and sensor systems. The programme covers optical diagnostics and includes modelling of industrial processes, fusion plasmas and special flow systems. Activities in three areas have increased on the basis of industrial needs and anticipated new research contributions. These areas are polymer optics, biomedical sensors and microflow systems.

The year has been characterised by comprehensive industrial collaboration, particularly in the areas of sensors and laser systems. Joint ventures with Kanitech A/S and Torsana A/S, as described on the introductory pages, included some of the major breakthroughs where the key competences of the programme are finding wide-ranging applications in industrial products.

Kamstrup A/S
Collaboration on industrial measuring techniques with Kamstrup A/S has been expanded to include several industrial sensors and new application technologies.

Steensborg – a CAT company
Work is being done to develop replication technologies for the graphics industry in collaboration with Steensborg Aps., a CAT company.

Intellix A/S
This company is developing software for knowledge-based systems. A licensing agreement has been entered into with the company, based on a new patented system developed by Risø. Ongoing joint development work is being carried out, part of it as an industrial post-doctoral project. Two priority patent applications have been submitted. The rights to one of the patents have been sold to Intellix A/S. The patents concern more rapid training of systems to recognise objects, e.g. recognition of diseased and healthy cells in a biological sample.

UNI-Sensor
A new system of optic edge detection of transparent plastic materials has been demonstrated to the firm UNI-Sensor. Using polarised light, the system makes it possible to establish the exact position of transparent plastic materials in production processes.

Ibsen Micro Structures A/S
A patent application has been submitted for non-contact measurement of rotation and torsion of rotating axles. This is part of an industrial research project in conjunction with Ibsen Micro Structures A/S. It is used in collaboration with JJ Measurement (a CAT company) for accurate measurement of angles of rotation, endowing a relatively simple and inexpensive mechanical device with a high degree of accuracy.

Expansion of key competences
A number of research programmes are supported by the EU and the Danish authorities.

JOULE
Work is being done on laser anemometry for wind turbines under the JOULE programme. A method of measuring immediate wind force at a distance of 100–200 m in front of a wind turbine is being developed. This makes it possible to determine the effectiveness of wind turbines, opening the way for active control of the wind turbines of the future. A patent for the system has been applied for, and collaboration has been entered into with three companies, two Danish and one British, supported by JOULE. Some of the technology is based on results of research into laser diagnostics for plasma physics experiments.

EURATOM
Full 3D real-time computer simulations have demonstrated the self-organisation of turbulence in a magnetised plasma. These numeric results are of great importance in the interpretation of the experimental results achieved with Risø's laser diagnostics, as discussed in the introductory pages.

BRITE
Composites of biological fibres and techniques to study their quality are being developed with the industrial materials programme as project leader. The optic aspect is to investigate methods for location of cavities and, hence, delamination within the material.

The Danish Natural Science Research Council
In collaboration with Brown University in the USA, Risø has developed a completely new type of computer program based on extremely accurate and effective "spectral methods" for calculating the interaction between light

and diffractive optical elements. These elements may have surface structures that vary on many different length scales in relation to the wavelength of the light. The new computer program, optimised for efficient execution on parallel supercomputers at UNI-C, will enable scientists to design a large number of new, miniaturised optic sensors.

The Danish Technical Research Council
Work is being carried out in a Ph.D. project where light is used to recognise and study the construction of tissue. The technology can be applied to track growth of cancer cells or to analyse the retina and blood circulation in the eyes in cases of diabetes, for example. The project is a spin-off of major related work on the diffusion of light in tissue; a theoretical description of the passage of laser light through tissue and other heterogeneous samples has been developed. Risø has demonstrated that the previous theory is not tenable and has proposed a new theory.

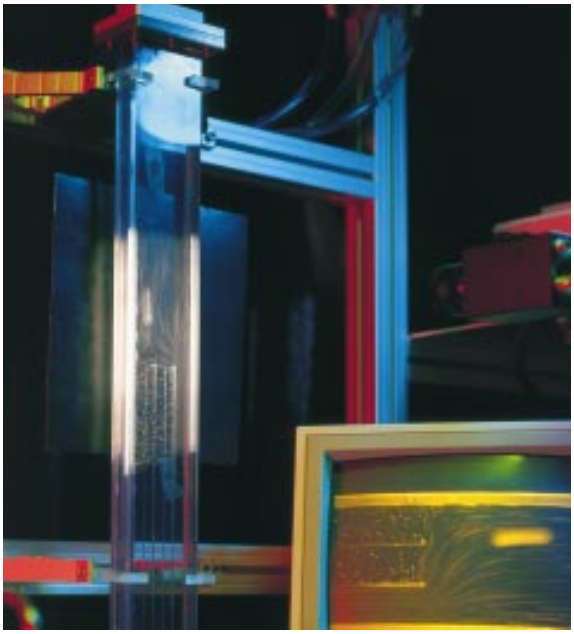
In a so-called Talent Project supported by STVF, a new optical "Smith card" for analysing phase contrast filtering has been published as a result of collaboration with the Japanese electronics company Hamamatsu Photonics. The Smith card is an accessory for system analysis and optimisation of systems; it can be used for encryption, for example of credit card codes used for access control. Instead of the existing magnetic card strip, the new system is optically based and offers greater security.

The Danish Academy of Technical Sciences
The Danish Academy of Technical Sciences has provided support for two industrial post docs and two Ph.D. students.

Speckle patterns with potential
A theoretical description has been prepared of dynamic speckle characteristics of surfaces in motion. This has implications for measuring mechanical movements and for medical diagnostics. Speckle patterns are a complex phenomenon that is simple to observe if a rough surface is illuminated with laser light. A spot with areas of light and dark can be seen, and the spot appears to "hover" on the surface. The theory of speckle patterns and their characteristics has been the basis for the development of FreePen, a replacement for the computer mouse, described in the introductory pages.

BRITE/EURAM project on fuel consumption in jet engines
Using infrared measuring equipment, FTIR, methods are being developed for the rapid measurement of the content and temperature of exhaust gases from jet aircraft engines.

Biological cells in microflows
In 1997, a new fluid experiment was designed and set up to study magnetic separation of biological cells in microflows. These studies are being carried out in conjunction with MIC at the Technical University of Denmark and have major practical implications for a number of new medical systems of diagnosis. The experimental studies are supported by numerical fluid calculations carried out in conjunction with UNI-C on their large supercomputers.


BOYE KOCH

The magnetic separation of biological cells in microflows is being studied in a new fluid experiment. Risø is collaborating with Mikroelektronikcentret (MIC) at DTU, and the experiments are of major practical significance in a number of new medical diagnostics systems.

Teaching and educational activities
A graduate school in nonlinear science has been established in collaboration with DTU, KU and Novo Nordisk A/S. The school will provide a Danish PhD-program at the highest international level, with the aim of preparing students to exploit and apply recent advances in nonlinear science to outstanding problems of science and industry. The school is sponsored by The Danish Research Academy.

A number of briefing sessions as well as lectures for industrial companies have been held, and plasma physics is being taught at the DTU.

The optics and sensor systems programme is based in the Optics and Fluid Dynamics Department.
In 1998, the department engaged 52 man-years, 15 of which involved Ph.D. students and post docs. The department's financial turnover was DKK 37.8 million, 13.5 million of which was derived from research contracts.
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Plant production and ecology

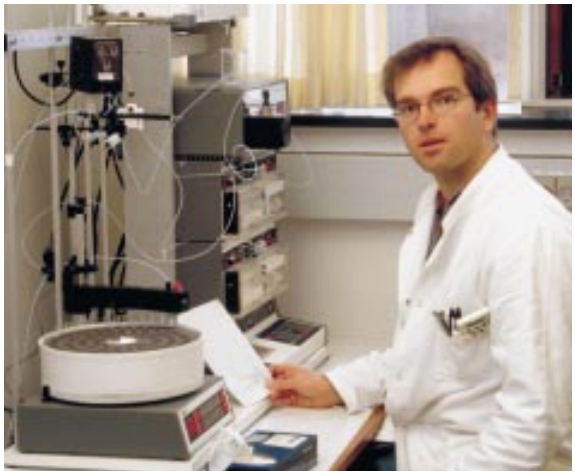
Care of the environment, resources, the economy and consumer demands has increased the need for profitable plant production of high quality with low consumption of resources and reduced impact on the environment. Risø's research aims to restrict the use of fertiliser and chemical plant protection agents by making use of the genetic basis of the plants in relation to resistance to plant diseases and for effective absorption and exchange of nutrients. Under particular scrutiny are problems relating to the use of genetic engineering, and pollution in connection with the leaching of nitrogen and phosphorus, the use of pesticides, organic pollution, trace elements in the human food chain and the significance of air pollution in relation to plant production.

DLF-Trifolium A/S

As discussed in the introduction, an agreement on strategic collaboration between DLF-Trifolium A/S and Risø has been signed for a joint research programme to provide the basic knowledge necessary to develop a new generation of genetically engineered grasses without stems and flowers. A joint research laboratory has been set up at Risø, making the project unique in Danish research.

The Cereal Network – collaboration with Danish grain refiners

An important tool for more efficient and faster development of new plant cultivars is the use of genetic markers (small DNA fragments indicating specific places on a chromosome where hereditary characteristics can be traced, thus giving a genetic fingerprint of the plant). This way, it is possible to produce and maintain breeding lines with high disease resistance and other desirable characteristics. A new technique for automatically detecting small DNA fragments using fluorescent dyes has been adopted. This rapidly locates genetic markers at the various chromosome positions. Using this method, a number of markers have now been mapped in a cross between the barley cultivars Alexis and Regatta. Combining this with previously mapped markers, the gene map for barley now has more than 151 markers. Reasons for high disease resistance of barley plants include the combined effect of genes with minor effect, so-called "quantitative trait loci" (QTL). Such QTLs determining resistance to powdery mildew and scald are located on barley chromosomes 3 and 6. Information on the malting quality of these lines is being gathered at breeding stations.



MICHAEL FISCHER

Brian K. Kristensen received his Ph.D. degree in 1998 in the Plant Biology and Biogeochemistry Department. His work is on the retarding effect of barley peroxidases on the development of attacks by patogenous disease.

New genes capable of resisting powdery barley mildew have been identified in wild barley *(Hordeum spontaneum)*. These resistance genes are being isolated and genetic markers are being developed. The resistant lines and their respective markers will be made available to Danish barley breeders so that they can introduce the genes into their breeding stock.

Carlsberg Laboratory

A contract has been entered into with the Carlsberg Laboratory for the cultivation of barley plants for use in Carlsberg Laboratory experiments.

Detoxification of flue gas

A new method, De-TAR, has been developed to reduce organic matter content in condensates from gasification facilities, for example. The method is based on catalytic oxidation and it has proved successful in laboratory tests. The method is now being evaluated in collaboration with industrial partners.

BioCrack A/S

A patent entitled "Process for Solubilising Hemicellulose" has been applied for jointly with BioCrack A/S.

The Ford Motor Company

In conjunction with the Ford Motor Company, Risø has been studying the environmental effects of new alternative materials, fuel cells and fuel additives.

Danish Environmental Protection Agency

On behalf of the Danish Environmental Protection Agency, Risø is studying absorption by plants of selected organic pollution from soil which has had slurry from cleansing facilities applied.

Consultative and technical support has been given to the Danish system of laboratory quality assurance, DANAK, as well as to the Council for Recycling and Cleaner Technology.

New knowledge of plants, biotechnology and particle exchange

Fighting powdery mildew

One objective of work on molecular plant pathology is to understand the mechanisms underlying resistance. This could lead to rapid isolation of new resistance genes that could be exploited, to defend for example barley against

powdery mildew infection, which in financial terms is one of the most serious diseases in plant production. If a specific avirulence gene in the pathogen causing the disease correlates with the corresponding specific resistance gene in the plants, then the pathogen cannot survive on the host.

So-called AFLP markers are used to map the avirulence genes in the barley powdery mildew fungus; in addition, ESTs are mapped in collaboration with the Carlsberg Laboratory. This mapping will form the basis for cloning avirulence genes.

In parallel with genetic mapping, physical mapping of the genome (i.e. of the entire genetic material in the organism) is carried out.

Transgenic plants and fungi

Genetically modified plants express new genes and it has been alleged that the "cost" to a plant of expressing the new genes reduces its viability. Risø has analysed this with a transgene inserted into oilseed rape to give resistance to the herbicide Basta, which has been bred into the weed field mustard *(Brassica rapa)*. The results show that this gene construction does not reduce the viability of the recipient plants.

Transformation by means of a gene gun has shown that a special molecule can be expressed in fungal spores making it possible to detect early stages of infection. This paves the way for easier and more rapid development and selection of biological resistant species of grain.

Methods have been developed for the transfer and selection of transgenic spores of the powdery barley mildew, *Erysiphe graminis f sp. hordei*, and a gene has been cloned which may prove an important factor in the development of the powdery barley mildew disease. These results open up the possibility of taking out patents on the technology and on the genes respectively.

The impact of the greenhouse effect on crops

Genetic variation was studied using genetic markers in three selected new and old strains of winter oilseed rape. The old strains were more genetically variable than the new strains. The ability of the strains to produce seed and above-ground biomass at a projected future higher level of CO_2 in the atmosphere was studied in controlled experiments at the Risø Environmental Risk Assessment Facility, RERAF. In the selected material, the increased levels of CO_2 produced a tendency towards a shorter growth period, increased water efficiency, reduced seed mass and increased dry-mass biomass production. No significant differences in seed yield were found between the two CO_2 levels.

Organic vegetables are different

Analytical methods for agricultural and market garden produce have been developed to identify the impact of production methods. Provisional results show that differences can be traced between conventionally and organically cultivated products.

BOYE KOCH

Risø has set up a joint research laboratory with DLF-Trifolium. Its purpose is to develop a new type of genetically engineered grass that does not produce stems or flowers and thus has greater nutritional value as pasture. Here, work is being done to isolate the growth point of the grass plant (meristem), from which the genes that control flower formation can be found. Standing in the photo is research manager Klaus K. Nielsen; seated, from left to right: Ph.D. student Klaus Petersen, laboratory technician Linette M. Jensen and researcher Thomas Didion.

Education of scientists

A number of lectures have been given at KU and KVL. The Nordic Academy for Advanced Study has given funding to a Nordic Ph.D. course on molecular communication in plant–microbe symbioses, to be held at Risø in August 1999. A Ph.D. course was run at KVL on DNA markers in plants.

A one-day conference has been organised at ATV for "Soil and Groundwater", a committee founded by ATV.

The plant production and ecology programme is based in the Plant Biology and Biogeochemistry Department.

In 1998, the department engaged 117 man-years, 30 of which involved Ph.D. students and post docs. The department's financial turnover was DKK 77.0 million, 37.4 million of which was derived from research contracts.

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Systems analysis

POLFOTO/THOMAS SØNDERGARD

Electric cars are moving forward technologically and may in future play a not insignificant role in the electricity balance market, according to new Risø studies.

As industrial and energy systems become increasingly complex and increased emphasis is placed on environmental considerations and human factors, Risø's research in systems analysis is directed towards these issues. It aims to cover the requirements of the chemical industry, the process industry, the transport sector, electrical utilities, authorities such as the Danish Energy Agency and the Danish Environmental Protection Agency, Danish consulting engineering companies and international organisations such as the EU and UNEP. The research covers methods and models describing the link between environment, economy and society with special reference to the energy, traffic, agricultural and industrial sectors.

During 1998, work has been directed towards the development of methods and tools for technical–economic optimisation and risk management, which will give Danish society, other countries and international organisations a better basis for making decisions on the development and use of new technologies, including the evaluation of environmental, economic and human consequences.

Prize for pilot training project

A virtual flight simulator developed in an EU joint venture between private companies and public research institutions was one of 25 prize-winners in the European IT Prize 1998 awards. In the MATE flight simulator, the buttons and instruments of the cockpit are represented on a number of touch-sensitive computer screens. The advantage of the virtual simulator is that it is possible to programme the system so that the simulator can simulate the configuration of instruments, buttons and control levers of many different types of aircraft. Risø's role in the project was the experimental verification of whether pilots training in a MATE simulator achieve skills similar to those obtained by training in an actual or replica aircraft cockpit.

Knowledge basis for future energy and technology planning

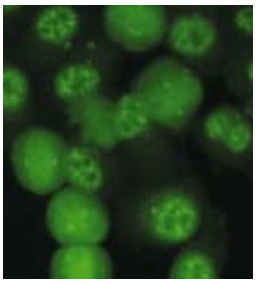
Production of energy without adverse effects on the environment, better co-operation between humans and complicated technique and assistance in difficult decisions about technologies of the future are calling for a solid knowledge basis which is accumulated through the key competencies in the programme area Systems analysis.

Preparations for new structures in the energy supply of the future

In 1998, methods and tools were developed for reduction of greenhouse gas emissions on an international level, e.g. joint implementation, trade with CO_2 quotas and analyses of deregulated electricity markets in Northern Europe.

Other important activities in 1998 included analyses of interactions between structural changes in the economy, technological development and energy consumption as well as the development of methods and models for calculating atmospheric emissions and generation of waste.

In analyses of new technologies and their assimilation into the energy system, activities have centred on sustainable energy, including large-scale wind energy and the impact of electric cars on the electricity market.



STATENS SERUM INSTITUT

CANTOR is designed to facilitate easier and more secure classification and diagnosis based on medical images. Pictured here is a sample from "autoimmune serology", where classification of the picture relates to a special type of autoimmune disease.

In a project under the EFP, studies continued into the reliability of wind turbines in close collaboration with Risø's wind turbine test station and the Danish wind turbine industry.

Joint DMU–Risø centre

In 1998, Risø entered into an agreement with Denmark's National Environmental Research Institute (NERI) on the establishment of Centre for Analysis of Environment, Economy and Society. The centre comprises the energy systems analysis programme at Risø and the Systems Analysis Department at NERI. The centre is managed jointly by Risø and NERI and became operational from January 1999.

Basic research centre for human–machine interaction

As described in the introduction, Risø hosts a basic research centre for human-machine interaction, established in 1998.

EU projects

A number of new EU projects were initiated in 1998 in

the areas of quality assurance, risk analysis and the atmospheric dispersion of hazardous substances.

Under the auspices of the EU-LIFE project on environmentally responsible decommissioning of ammunition, a provisional assessment has been made of different processing and decommissioning techniques. The assessment includes environmental and health considerations along with economic factors. One of the atmospheric dispersion projects is concerned with methods for calculating fluctuations in the concentration of dangerous emissions. Risø is the Danish representative in a new EU network approaching industry with information on EU industrial safety projects.

Interpretation of medical images
The EU Telematics Healthcare Programme is financing a new project, CANTOR. Its purpose is to improve education and training, quality assurance and standardisation of object recognition and classification of images used inter alia in the diagnosis of cancer. Risø is co-ordinating the project and is responsible for eliciting user requirements for the system, and for evaluating the system once it has been implemented.

The World Bank
In collaboration with the World Bank, local authorities and research institutions, Risø is working on adjusting models and methods from Danish energy planning for planning purposes in Mexico.

GEF and UNEP
The UNEP Centre has been continuing its activities in developing and testing guidelines for analysing national strategies to reduce greenhouse gas emissions, in collaboration with national teams in a number of countries in Africa, Asia, Latin America and Eastern Europe. Emphasis is also put on building up national capacity. A number of reports have been prepared under the programme and, the UNEP Centre has organised regional seminars in all regions. Danida and the World Bank have co-sponsored the seminars, which like other activities are funded by GEF and UNEP.

The Kyoto Protocol
The establishment of the Kyoto Protocol has given the UNEP Centre new tasks. One example in 1998 was a collaboration with UNEP and the Ghanaian Ministry of the Environment on a regional seminar for African climate change convention negotiators, which was held in Accra, focusing on African perspectives for climate policy and sustainable development. The seminar was sponsored by Danida.

Staff members of the Centre are actively involved in the activities of the IPCC and have been invited as lead authors for the third IPCC assessment report. The Centre will also support UNDP and UNEP in the implementation of a new overall programme in support of the development of national reporting to the climate convention, financed by GEF and a number of bilateral donors.

BOYE KOCH

A virtual flight simulator developed in an EU venture between private companies and research institutions was one of the 25 winners of the European IT Prize 1998 awards. Pictured here is project manager Steen Weber (standing to the right of the monitors), together with some of his colleagues: from left, Erling Johannsen, Cecilia Steck and Vivi Hansen.

Scenarios for new technologies
The Technology Scenarios programme was established in 1998. The theoretical and methodological basis of the programme has been developed from three pilot projects. Applications of superconductive thin film technology have been investigated in conjunction with NKT Research Center A/S. Two projects have been initiated in collaboration with the Department of Plant Biology and Biogeochemistry, relating to the production of foodstuffs and risk assessment. In addition, a small technological strategy project was carried out for Dantec Measurement Technology A/S in collaboration with the Department of Optics and Fluid Dynamics. Forty-five delegates attended a seminar on technology scenarios organised for the occasion of the second meeting of the programme's scientific advisory panel.

Teaching and educational activities
Risø scientists have contributed to courses on industrial safety and hazardous waste in Thailand and Poland.

The systems analysis programme based in the Systems Analysis Department.
In 1998, the department engaged 57 man-years, 8 of which involved Ph.D. students and post docs. The department's financial turnover was DKK 50.0 million, DKK 30.3 million of which was derived from research contracts.
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Wind energy and atmospheric processes

Risø's research into wind energy and atmospheric processes aims to advance the international competitiveness of the Danish wind turbine industry, setting the scene for implementing a Danish energy policy in the area of wind energy and furthering the global application of wind power. The programme also covers research into the atmospheric physics basis of assessing and forecasting wind effects, transport, conversion and exchange of air pollution and other airborne particles, together with the consequences of accidents.

Industrial collaboration

Wind atlas of Egypt
Work began during 1998 on a wind atlas of Egypt. The project is one of the largest wind resource studies ever, making use of advanced wind flow modelling as well as meteorological and satellite data. It is sponsored jointly by the Danish and Egyptian governments and is being carried out in conjunction with the Egyptian meteorological institute and the New and Renewable Energy Authority (NREA) in Cairo. The contract was negotiated with Danida.

Extreme winds in Denmark
In the EFP WAsP Engineering project, a numerical tool is being developed in consultation with a Danish consultant to calculate extreme winds and turbulence for determining the load-basis for wind turbines for arbitrary siting in Denmark using the WAsP method. Among other aspects, the analysis supports the reduction of extreme winds over large parts of Denmark put forward in the new Danish standard on wind load.

Wind turbine loads and safety
A numerical tool for probability analysis of loads and stresses in wind turbine components has been developed in collaboration with colleagues in Denmark and abroad. It can be used in standardisation work and as an instrument for the industry and the approval system.

Improved calculation tool for the wind turbine industry
Aerolasticity describes the relationship between the structure of a wind turbine, the flexibility of the structures and the flows around the wind turbine. This is a key point in the design of wind turbines. The results of this research are implemented within the HawC aerolastic program, developed by Risø. The program is used e.g. in the wind turbine industry to determine loads and optimum dynamic characteristics in the development of new MW-size wind turbines. As discussed in the introduction, the programme has been used in the design of the Bonus 2 MW wind turbine.

Numerical wind tunnel
Wind turbine manufacturers can save costly development time by carrying out profile tests in Risø's virtual wind tunnel – the numerical wind tunnel – instead of in a "real" wind tunnel. Risø and DTU have developed the Navier-Stokes EllipSys2D/3D calculation program which is well suited to performing calculations in the numerical wind tunnel. One of the more promising results from 1998 is a new method of extracting blade profile data, intended for use in the so-called BEM method, a standard aerodynamic calculation tool in the Danish wind turbine industry.

Calculation and design of blade profiles
In 1998, for the first time, a set of reliable 3D blade profile data was calculated for a complete rotor in the numerical wind tunnel. The problem of double stalling (the fact that a wind turbine can stall in two different ways in relation to the same wind flow) has a number of negative effects on stall-regulated wind turbines. CFD calculations have now demonstrated that the leading edge of the blade profile can be modified to minimise the problem. A new blade profile design tool has been developed in the EFP "Blade Design" project; this has been used in the design of a new range of blade profiles giving inter alia improved stalling characteristics, greater aerodynamic conversion efficiency and elimination of the double-stalling tendency.

Testing large blades
Risø's largest investment in facilities for servicing the wind turbine industry is the blade-testing facility at Sparkær, Jutland. Testing in 1998 included tests on the new MW-size wind turbines as part of the development and certification processes. In 1998, Risø was accredited by DANAK to carry out static and dynamic blade tests in Sparkær.

Additional accreditation
In 1998 the accreditation by DANAK was extended to include power curve measurements, measurements of structural loads on wind turbines and static and fatigue testing of wind turbine blades. Testing was performed on wind turbines in the range 0.5-1.5 MW situated in Denmark, Germany and California. Accreditation has also been achieved to conduct Dutch wind turbine type-approvals.

Det Norske Veritas, DNV
The fruitful collaboration on Danish and international approval of wind turbines between Risø and DNV has continued and plans for expansion are underway.

Forecast of wind produced electricity for Danish utility companies
A project on short-term forecasting of the production of wind energy in collaboration with EPRI and Danish utility companies has been concluded. The system is now running online with two updates per day. Participating organisations can access it via the Internet.

Wind turbines in weak power grids
The problems of wind turbine parks in weak power grids in India have been mapped in collaboration with DEFU and an Indian research institution and with support from EFP. The project is expected to lead to recommendations for optimised electrical design and regulation, which could also enhance the opportunity for Danish industry to supply integrated solutions.

Vestas and ABB
In co-operation with Vestas and ABB, a first generation combined variable speed and pitch controlled wind turbine has been developed, with significantly reduced loads in the transmission system as a result. Subjects for further investigation and optimisation have been identified, such as an aerodynamic design adapted for variable speed operation and further optimisation of the regulation.

New concept in wind turbines
A new flexible wind turbine concept has been developed with support from EFP (the Danish Energy Research Programme) and EU-Joule in co-orporation between research institutes and a blade manufacturer. The concept is characterised by a free yawing down wind turbine with nacelle tilting flexibility and a two-bladed teetering rotor with three-point supported blades and built-in structural couplings. Active stall and active coning control power and loads.

New testing facility in preparation
Work continues on establishing Risø's new testing facility in north-western Jutland for large wind turbines. Testing activities are expected to be ready to commence in late 1999, subject to approvals of applications pending with the relevant authorities.

Development of competences through broad research collaboration
The programme works closely with the Danish wind turbine industry, the Danish Energy Agency, the Ministry of Energy and the Environment, DMU, DMI, DTI, DNV and a number of Danish and foreign universities and research institutions. EU research programmes as well as programmes organised under the auspices of the Ministry for Energy and the Environment have sponsored a large proportion of research activities. In addition, agencies such as IEC, CENELEC, EUREC-Agency, IEA and EWEA are represented as participants.

The atmosphere on Mars
During the 1997 NASA Pathfinder mission, readings were taken of the atmospheric boundary layer on Mars. Risø participated in the international group responsible for analysing and interpreting these measurements in 1998.


BOYE KOCH

Risø has a patent pending for a wind turbine with a new type of hub. Pictured here, are four of the inventors, Flemming Rasmussen (outmost left), Jørgen Thirstrup Petersen (outmost right) of the Wind Energy and Atmospheric Physics Department, Preben Ellebæk of IT-Service Department (no. two from left) and Bjørn S. Johansen of the Materials Research Department.

Atmospheric fluxes over land and sea
Exchange between the atmosphere and land and sea surfaces of air-borne pollution, nutrients and greenhouse gases, as well as heat and water vapour, have been studied with particular regard to climate research in a broad-based Nordic – European joint venture. The absorption of carbon by forests is under investigation in the EUROFLUX project, for which Denmark is taking readings in a beech-wood near Sorø.

Dissemination and educational activities

Education
Participation in graduate education schemes has increased with teaching on a course in wind turbine technology under way at DTU and implementation of a course in boundary layer meteorology and turbulence; and a degree programme at the KU Geophysics Institute. Finally, four university students are being trained at Risø. A course on the use of WAsP has been held with participants from the wind turbine industry.

Co-ordination of the European wind energy conference
Planning and co-ordinating the European wind energy conference, carried through in March 1999, was a major task in 1998. The chairman of the conference and the programme chairman were both selected from Risø's department of Wind Energy and Atmospheric Physics.

The wind energy and atmospheric processes programme is based in the Wind Energy and Atmospheric Physics Department.
In 1998 the department engaged 88 man-years, 10 of which involved Ph.D. students and post docs. The department's financial turnover was DKK 77.3 million, 50.3 million of which was derived from research contracts.
Head of Department: Erik Lundtang Petersen, Ph.D.

Phone: +45 4677 5000. Fax: +45 4677 5970
E-mail: vea@risoe.dk

Web site: www.risoe.dk/amv

Nuclear safety

Risø is the only Danish research centre combining the fields of nuclear safety, radiation protection, radioecology and development of nuclear measuring techniques. The research in this programme addresses the needs of governmental authorities and others for consultancy on nuclear and radiation matters and the operation of Risø's own nuclear facilities. Risø participates in joint ventures, as defined by international treaties, in the areas of the environment and reactor safety. Risø contributes to national nuclear emergency preparedness initiatives and is responsible for temporary storage of all Danish radioactive waste.

Commercial production of semiconductor materials
A new horizontal irradiation facility for neutron transmutation doping of silicon came into operation in 1998, and commercial irradiation of silicon for the manufacture of semiconductor materials is now fully operational.


RISØ

Cleaning of radioactively contaminated house walls in the Ukrainian town of Pripiat, 3 km from the site of the accident at the Chernobyl nuclear power plant. The town was evacuated in the initial days following the accident in 1986. Risø has developed strategies and gained experience with effective cleaning of radioactively contaminated urban areas. It will now be possible for the population to move back into some of the areas affected by radiation.

Elsamprojekt A/S
Risø and Elsamprojekt A/S are participating in a Danish–American–Belarussian joint project to identify possible safe applications of the large quantities of radioactively contaminated bio-materials from the Belarussian forests, in energy production. Both the current radiological situation in the areas affected by the Chernobyl accident and the dose levels that may arise as a result of energy production have been analysed.

Forsmark
Under contract to the Swedish Forsmark nuclear power station, Risø has carried out Monte Carlo calculations of neutron activation of reactor components close to the reactor core of one of the power station's production units.

H+H Industri A/S
At the request of H+H Industri A/S, which manufactures building materials, Risø has developed a method for laboratory measurement of radon emissions from building materials. The method makes it possible to scale the results for standard house conditions. The measurements have confirmed that ordinary Danish building materials are not a significant source of radon in the indoor atmosphere.

Danish and international consultancy
Risø has contributed to an EU EURADOS working group, which is concerned with harmonisation and dosimetric quality assurance in monitoring individuals for external radiation. One of the tasks of the working group is to organise a performance test for body dosimeters from the European countries for measuring beta, photon and neutron radiation. To this end, Risø has irradiated dosimeters from participating states with beta test doses.

In collaboration with TNO in the Netherlands, Risø has contributed to the preparation of a document discussing criteria and protocols for laboratories providing dosimetry services for quality control in diagnostic radiology. The work is supported by the EU.

The international status of nuclear power
In 1998, the fourth annual report on the international status of nuclear power was published in Danish. The report has been distributed to politicians, officials and other interested, as well as to the Danish media.

The Danish knowledge base in the nuclear field
The development of a new type of beta spectrometer has continued as part of a three-year EU research project on dosimetry for beta and low-energy gamma radiation. An important objective is to produce a compact, flexible beta spectrometer for use in measuring under normal working conditions as well as in the event of accidents. All software development for the spectrometer has made use of LabVIEW™ software.

Decontamination in towns polluted by Chernobyl
Risø has carried out decontamination in two radioactively polluted towns in Russia. These efforts show that reductions in dose rate are achievable, by a factor of 3–4 indoors and a factor of 4–6 outdoors. Reductions of this magnitude make it possible to allow the population to move back into some of the affected areas.

Groundwater influx into the Baltic Sea
Risø takes part in an EU project to track sub-sea groundwater influx into an area of the Baltic Sea. Radon and radium in sea water are used for this purpose, and a semi automatic measuring system has been developed. The method uses thermal traps for gathering radon which is measured using scintillation cells.

Nordic preparedness
Responsibility for the management of the BOK-1 project in the NKS programme for 1998–2001 has been passed to Risø. This is a preparedness project in relation to acci-

dents involving nuclear power. The project covers quality assurance of laboratory measurements, strategies for mobile measurements, use of data from field measurements and agricultural and forestry counter-measures, as well as emergency preparedness drills. There will be special emphasis on incorporating environmental surveillance data into nuclear preparedness decision-support systems.

Hazardous aerosols

Fine aerosols, particularly particles less than 100 nanometres in diameter, have attracted increasing attention in recent years because health studies show a link between mortality and particulate air pollution. In conjunction with DTU and FLS miljø A/S, Risø is analysing gas aerosols from chimney outlets at five Danish power stations. The project is supported by the Ministry for Energy and the Environment under EFP-98. Risø is analysing the basic composition of matter in the aerosols using neutron activation analysis.

Source identification using plutonium

The relative distribution of plutonium isotopes can be used for source identification. Using mass spectrometry, Risø has studied plutonium isotope rates in the sea at Thule, Greenland and from the Ob-river system that receives discharges from the Russian nuclear factory at Mayak in the Urals.

Mats Eriksson is a Ph.D. student in the Nuclear Safety Research and Facilities Department. He works with aquatic radioecology of actinides and long-lived fission products.

At Thule, it was found that the plutonium from the accident in 1968 must have come from at least two different productions. New sensitive mass spectrometers have significantly increased the accuracy of isotope determination. Thus they can be used for source identification, because isotope conditions will vary depending upon whether the plutonium has originated from for example the aircraft crash at Thule, from the Mayak emission, global fallout, Chernobyl, Sellafield or La Hague.

Education and courses

In 1998, a scientist from Risø held a course in reactor physics at the DTU, while every year, an experimental course is run at the DR1 training reactor for engineering students from the DTU. Risø scientists teach health physics, radioecology and radiation instruments at DTU alternate years.

BOYE KOCH

Optically stimulated luminescence methods are being developed for the reconstruction of doses received by the population in the wake of nuclear accidents. New, powerful stimulation units based on blue, infrared and laser diodes has improved the sensivity by a factor of 10. The system enables dosimetry of individual grains of quartz and the equipment has been sold to a large number of research laboratories around the world.

Three Risø scientists presented lectures at "The Nordic–Baltic Course in Environmental Radioactivity" at the University of Lund in May 1998, and a Risø scientist gave a lecture on radioecology at Copenhagen University in April 1998. Two students from the DTU carried out their concluding project at Risø, developing a radiochemical procedure for neptunium determination. Four Lithuanian guest scientists have been trained in radiochemical analysis, gamma and alpha spectrometry and modelling. Guest lecturers from Finland, The Netherlands, Lithuania, the UK and the USA took part in the dosimetry research. Every year, some 40 upper secondary school classes carry out one-day or half-day experiments at the DR1 training reactor. The number of upper secondary school pupils visiting DR1 in 1998 totalled approx. 600.

The nuclear safety programme is based in the Nuclear Safety Research and Facilities Department.

In 1998, the department engaged 143 man-years, 4 of which involved Ph.D. students and post docs. The department's financial turnover was DKK 111.7 million, 30.8 million of which was derived from research contracts.

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Web site: www.risoe.dk/nuk

Publishing activities

Risø's research results in comprehensive publishing activity through articles in international journals, research reports and other publications. This publication activity forms the basis for the dissemination of knowledge and technology to industry and for the exchange of knowledge with Danish and international research institutions. A list of all Risø publications in 1998 is published in the report Risø-R-1097.

Figure 1. Risø's total annual publication activities in the period 1989–1998.

Figure 1. Annual publication activity (number)

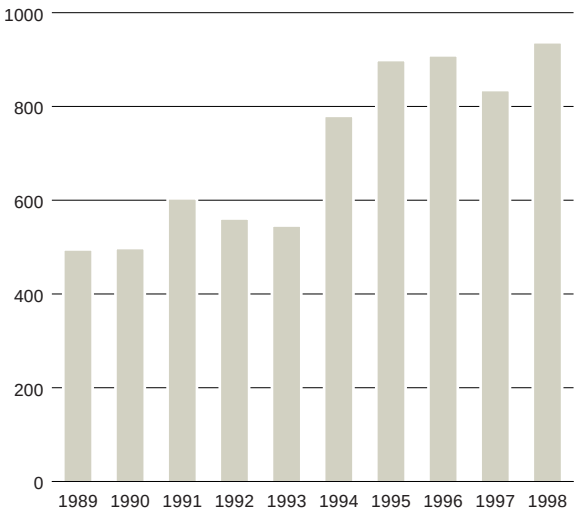


Figure 2. Number and distribution of Risø's publications in the period 1994–1998 and number of unpublished lectures in the same period.

Figure 2. Publications and lectures (number)

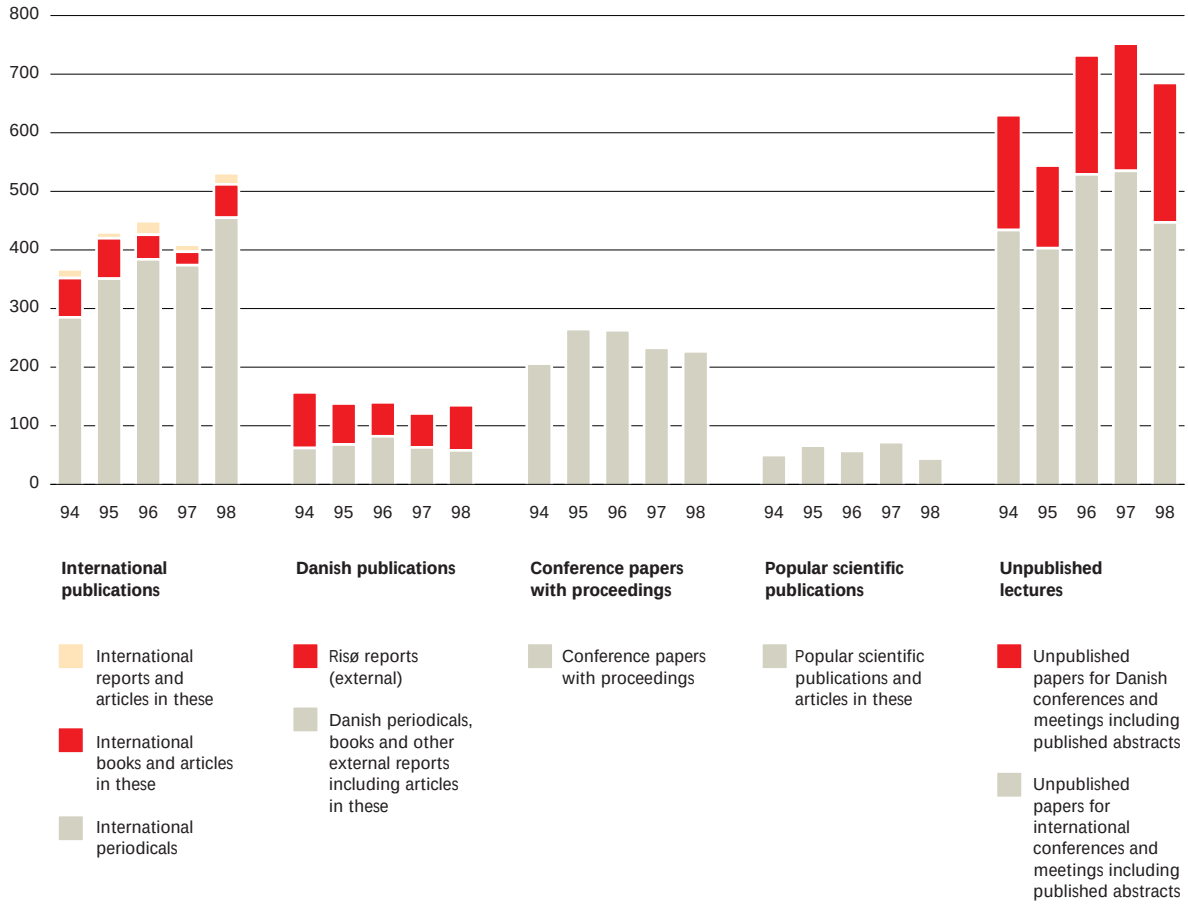


Figure 3. Articles in ISI Source Journals

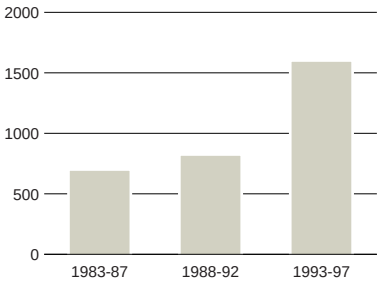


Figure 4. Citations

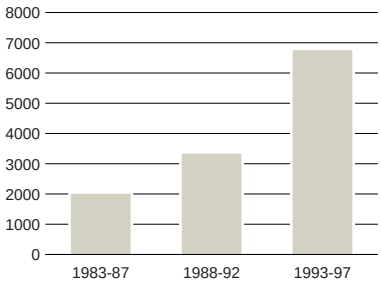


Figure 5. Citations per article

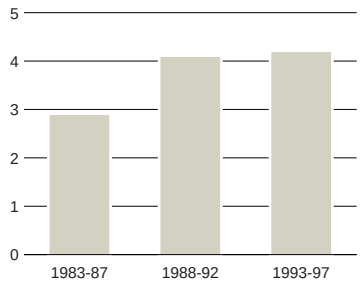


Figure 3. Risø's articles in ISI Source Journals in the period 1983–1997, specified in five-year periods.

Figure 4. Number of citations from Risø's articles in ISI Source Journals specified for the same five-year periods within which the articles were published.

Figure 5. Average number of citations per Risø article specified for the same five-year periods within which the articles were published.

Risø's articles in ISI Source Journals in the period 1983-1997

The Institute for Scientific Information (ISI) indexes more than 4000 international journals in the field of the natural and technical sciences, and approx. 3000 journals in the humanities and social sciences (ISI Source Journals). ISI publishes several different products based on Source Journals, including the Science Citation Index, which is used in connection with citation analyses. Risø subscribes to ISI's Institutional Citation Report (ICR), which is a database of references to the articles in ISI's Source Journals, in which Risø is given as the author's address. The database includes information on the number of times the individual articles have been cited and the expected number of citations of articles. Comparison of one five-year period with the preceding five-year period shows that both the number of publications and the number of citations is increasing (Figures 3 and 4). The database also makes it possible to analyse Risø's publication patterns, i.e. which journals publish most Risø articles. Figure 6 shows the 25 journals in which Risø has published most articles within the last five-year period 1993–1997. The database also makes it possible to illustrate Risø's collaboration with other research institutions. Figure 7 shows the 25 institutions with which Risø has jointly published most articles in the period 1993–1997.

Figure 6. The 25 ISI Source Journals in which Risø has published most, within the period 1993–1997.

Journal	No. of articles	No. of citations	Citations /article
Physical Review B	54	249	4.61
J Physical Chemistry	48	411	8.56
Physical Review Letter	48	534	11.13
Macromolecules	37	614	16.59
Physica B	36	100	2.78
J Physics-Condensed Matter	34	153	4.50
J Nuclear Materials	32	125	3.91
Chemical Physics Letters	31	293	9.45
Physica C	26	86	3.31
Radiation Measurements	26	98	3.77
Europhysics Letters	20	88	4.40
Radiation Phys Chem	20	18	0.90
J Applied Physics	19	31	1.63
Radiation Protec Dos	17	42	2.47
J Magnetism Magnetic Materials	15	35	2.33
Materials Sci. Forum	15	19	1.27
Surface Science	15	31	2.07
Acta Metallurgica Materialia	14	68	4.86
Hereditas	14	46	3.29
Langmuir	14	65	4.64
Physical Review E	14	43	3.07
Plant Soil	14	34	2.43
Solid State Ionics	14	35	2.50
Int J Chem. Kinetics	13	109	8.38
J Applied Crystallog.	13	65	5.00

Figure 7. The 25 institutions with which Risø has jointly published the most articles in the period 1993–1997. (ISI Source Journals).

Institutions	No. of articles
Technical University of Denmark	100
University of Copenhagen	67
Ford Motor Co.	54
Russian Academy of Science	39
KFA Jülich GmbH	33
University of Oxford	33
Danish National Environmental Research Inst.	31
University of Minnesota	30
The Royal Veterinary & Agricultural University	28
Aarhus University	27
Oak Ridge National Laboratory	27
Weizmann Institute of Science	27
AT&T Bell Labs	24
Rutherford Appleton Laboratory	18
Brookhaven National Laboratory	16
ETH Zurich	16
Inst Max von Laue Paul Langevin	16
Swedish University of Agri. Science	16
European Synchroton Radiation Facility	15
University of Hamburg	15
Hahn Meitner Inst. Kernforsch Berlin	14
University of Toronto	14
CEA	13
Chalmers University of Technology	13
DESY	13

Education and skills development

Education of scientists

Nineteen Ph.D. students attained their Ph.D.s in 1998. Seventy-two Ph.D. students, representing a total of 57 man-years, were associated with Risø in 1998. Forty-four of the students received a grant co-financed by the Research Academy and Risø; five were financed by the Engineering Science Centre and 23 were financed from other sources. The number of post doc grants is 58, corresponding to 46 man-years. The pilot experiment under the auspices of the ATV's Committee on Industrial Ph.D.s with industrial post-doctoral projects has now become a permanent arrangement. Two projects have been completed and six new projects have been initiated.

Ph.D. degrees, prizes and other distinctions awarded in 1998

Industrial Ph.D. course
The following were awarded Ph.D. degrees following completion of an industrial Ph.D. course:
Flemming Bay Anderson, M.Sc., in a joint venture involving Skamol A/S, Kemisk Insitut, AU and Risø National Laboratory, Materials Research Department.
Bjarke Rose, M.E., in a joint venture involving Ibsen Micro Structures A/S, Mikroelektronik Centret and Risø National Laboratory, Optics and Fluid Dynamics Department.

Materials Research Department

The following Ph.D. degrees were awarded:
Peter Anker Thorsen, M.Sc., H.C. Ørsted Institutet
Jesper Vejlø Carstensen, M.E., DTU
Steen Arnfred Nielsen, M.E., DTU

Travel bursary
Dorte Juul Jensen received an award from "Tagea Brandts Rejselegat".

Awards were made from the following funds and foundations:
Henning Friis Poulsen was awarded Hede Nielsen Prisen for his research into "Transmission in Superconductive Materials".
Carsten Bagger, Bruno Kindl and Mogens Mogensen were awarded Patentprisen '98 for "Solid Oxide Fuel Cells with LSM and YSZ Cathode".
Torben Lorentzen has received support from Direktør, dr.techn. A.N. Neergaard og Hustrus Fond for to prepare the textbook "Introduction to Characterisation of Residual Stress by Neutron Diffraction".
"Civilingeniør Frederik Leth Christiansens Almennyttige Fond" has given support to senior scientist Aage Lystrup for the acquisition of new equipment for testing fibre composite materials.

Condensed Matter Physics and Chemistry Department

The following were awarded Ph.D. degrees:
Mogens Larsen, M.Sc., KU
Nils Berg Madsen, M.E., DTU
Morten Ring Eskildsen, M.E., KU
Thomas Schultz, M.Sc., AU
Steen Aagard Sørensen, M.Sc., KU

Private funding:
Senior scientist Peter Sommer Larsen received a grant from "Fabrikant Mads Clausens Fond".

Travel bursary:
Morten Ring Eskildsen was awarded a travel bursary from the "Christian og Anny Wendelbos Fond".

Skills development

An ongoing commitment to education and the development of expertise is central to Risø's key position in Danish and international research.

Thus, Risø continues to target its education efforts towards department heads as well as other employees. Offers of continuing education are provided in part through Risø's internal education programme and partly through offering external courses. The main purpose of Risø's internal education programme is to offer education specially aimed at and developed for Risø staff. In connection with the implementation of Risø's new Føniks (SAP/R3) financial management system in the first part of 1998, Risø has, therefore, implemented a very comprehensive training programme in the use of Føniks. In addition, project manager training and programme manager training has been implemented, together with a number of other targeted activities for special groups of personnel. One spin-off of these courses is frequently the formation of user groups.

The personnel office has also created frameworks for development of expertise in organisational units, some of which, for example, have been organised in connection with Risø's central workshop refurbishment project. The purpose of the project is to prepare the central workshop for its future role at Risø as an alternative workshop, delivering high-quality results flexibly and effectively. Risø has received DKK 200,000 of support for the project from the Development and Reconstruction Fund. A number of craft-workers have been transferred to the status of research technicians to work on the project. Furthermore, Risø has received DKK 300,000 of support from the Development and Reconstruction Fund for the "Selling research to industry" project. To support the objective of the contract for increased industrial contact, the personnel office has developed this course in collaboration with a consultancy firm; the course will be implemented in 1999.

Risø implemented a new salary system for the academic staff in 1998. With a view to supporting the work on the new salary system, the personnel office has held seminars for the management group so that Risø can use salaries as an active instrument to show recognition for the demands placed on staff.

Optics and Fluid Dynamics Department

The following Ph.D. degrees was awarded:
Martin Løbel, M.E., DTU

Travel bursary
Palle G. Dinesen received an award from the "Christian og Anny Wendelbos Fond".

Plant Biology and Biogeochemistry Department

The following Ph.D. degrees were awarded:
Lene Krogh Christensen, M.Sc., KU
Brian K. Kristensen, M.Sc. (agri.), KVL
Anna Carina Simonsen, M.Sc., KVL
Sabine Ravnskov, M.Sc., KU

Wind Energy and Atmospheric Physics Department

The following Ph.D. degrees have been awarded:
Morten Nielsen, M.E., DTU
Anna Maria Sempreviva, M.Sc., KU
Jørgen Brandt, M.Sc., KU

Nuclear Safety Research and Facilities Department

The following Ph.D. degree was awarded:
Hans Peter Metz, M.E., DTU

Board of Governors, Management and Organisation

Board of Governors

Professor Ulrik V. Lassen, M.D.
Novo Nordisk Fonden
Chairman of the Board

Inge Thygesen, Senior Advisor
Ministry of Finance
Vice Chairman of the Board

Poul Skovgaard, Director

Jørgen Mads Clausen, Managing Director
Danfoss A/S
From 1 September 1998

Professor Knut Conradsen, Vice Rector
The Technical University of Denmark

Jørgen Elikofer, Development Manager
Danish Metalworkers' Union

Per Buch Andreasen, M.D., Dr.Med.Sc.
Copenhagen District Hospital, Gentofte

Birte Skands, Development Manager
Carlsberg A/S

Jens Olsson, Research Technician
Risø National Laboratory
Elected by Risø's personnel

Adjunct Professor
Kurt Nørgaard Clausen, Ph.D.,
Head of Programme
Risø National Laboratory
Elected by Risø's personnel

Søren Dalby, Development Manager
Herning Institute of Business
Administration and Technology
Until 31 August 1998

Secretariat of the Board
Management Secretariat
Lisbeth Grønberg, LL.M.
Risø National Laboratory

BOYE KOCH

Management

Jørgen Kjems, Ph.D., Managing Director
Jørgen Honoré, M.E., Bachelor of Commerce,
Vice Director from 1 October 1998

Lisbeth Grønberg, LL.M., Acting Vice Director
until 1 October 1998

Lisbeth Grønberg, LL.M.
Management Secretariat

Niels Hansen, Dr.Techn.
Materials Research Department

Professor Klaus Bechgaard, Ph.D.
Condensed Matter Physics and Chemistry Department

Adj. professor, Lars Lading, M.E.
Optics and Fluid Dynamics Department

Arne Jensen, M.Sc.
Plant Biology and Biogeochemistry Department

Hans Larsen, Ph.D.
Systems Analysis Department

Erik Lundtang Petersen, Ph.D.
Wind Energy and Atmospheric Physics Department

Benny Majborn, Ph.D.
Nuclear Safety Research and Facilities Department

Ulla Rasmussen, LL.M.
Personnel Office

Leif Sønderberg Petersen, M.Sc.
Head of Press Relations, Science Journalist

Hanne Troen, M.E
Safety Office

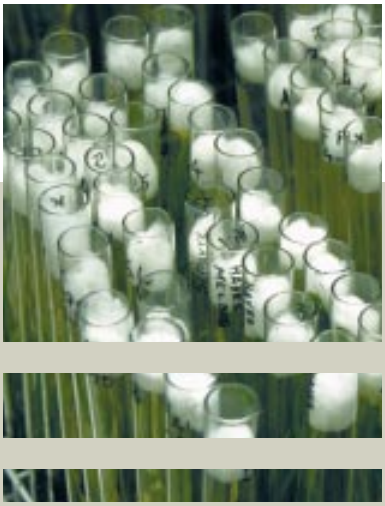
Freddy Mortensen, B.Sc.
Building and Construction
Service Department

Erik Kristensen, B.Sc.
IT-Service Department*

Birgit Pedersen, Librarian RLS
Information Service Department

Minna Nielsen, M.A.
Economy Department

* Established 1 February 1999. Formerly
the Engineering and Computer Department



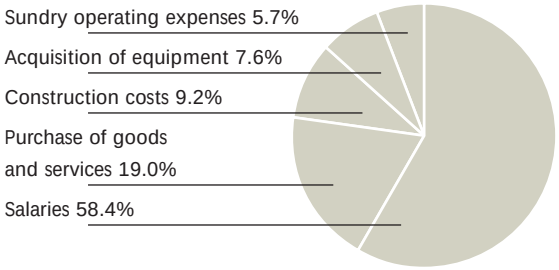
MICHAEL FISCHER

Finances

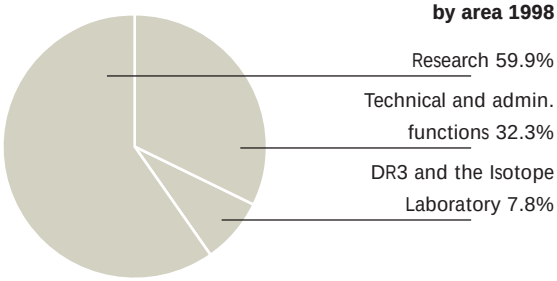
Operating statements for the state institution Risø	Accounts 1997	Accounts 1998	Budget 1999	Notes
DKK million at current prices (excluding VAT)				
Government appropriations for operating, plant and equipment costs	260.1	262.8	273.7	
Contracts earnings	222.1	235.3	243.2	
Total Income	**482.2**	**498.1**	**516.9**	
Wages and salaries	278.6	283.9	297.8	
Other operating costs	162.7	173.5	179.4	
Investments	23.1	46.4	52.3	1
Total Expenses	**464.4**	**503.8**	**529.5**	
Result (to be carried forward)	17.8	-5.7	-12.6	

1: Of which DKK 10.1 million were plant and equipment expenses in the National Accounts

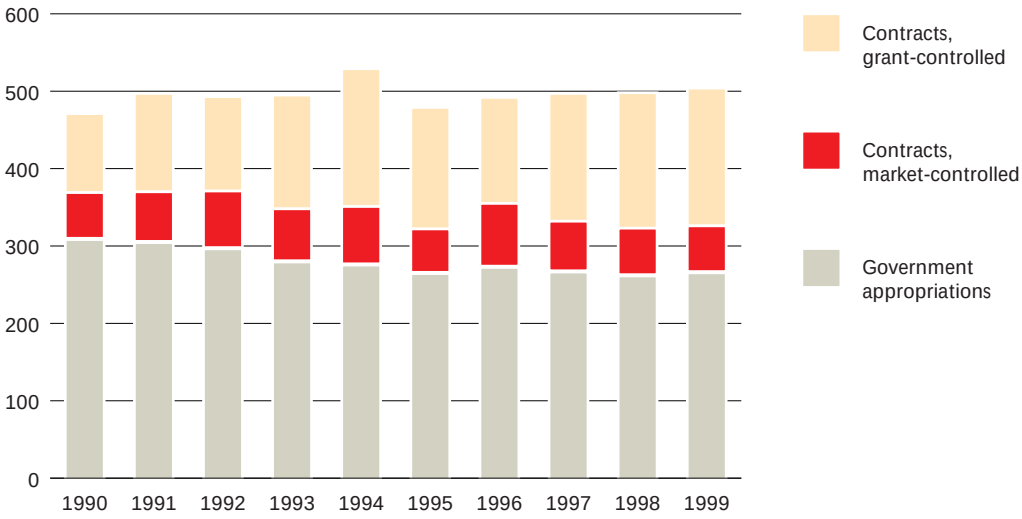
Percentage distribution of expenses 1998



Distribution of expenses by area 1998



Income development (1998 price-level, DKK million)



Balance sheet at the end of December	Accounts 1997	Accounts 1998	Notes
DKK million at current prices (excluding VAT)			
Assets			
Tangible fixed assets	233.0	231.7	1
Current assets:			
- Liquid holdings	1.2	2.6	
- Accounts receivable	105.4	94.5	2
Total assets	**339.6**	**328.8**	
Liabilities			
State financing of Risø's activities:			
- State financing of plant and equipment	233.0	231.7	
- Accumulated result from operations	19.7	14.0	
- State financing of other assets	57.1	53.3	
Short-term debt	29.8	29.8	
Total liabilities	**339.6**	**328.8**	

Notes:

1: The book value of fixed assets at the end of 1998. The amount is an accumulation of disposals, acquisitions and construction through the years reduced by the value of depreciation. 5% of the accumulated balance is depreciated using the straight-line method according to the Budget Guidelines. In comparison, Risø's property was valued at DKK 373.6 million in the official property valuation in 1997. Machines, fixtures and fittings are usually not included in fixed asset book values. Note that, as of 1 January 1998, eight service buildings were transferred to Statens Ejendomssalg A/S. In the National Accounts, these were listed as having a total book value of DKK 64,000 and were valued at a total of DKK 9.3 million in the official property valuation in 1997.

2: Of which costs met to be invoiced in the following financial year (EU projects, etc.)

Accounts 1997	Accounts 1998
29.8	35.1

Development in personnel 1990-98, man years

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Academic staff	308	305	319	345	357	355	360	342	356
Technical/administrative staff	574	524	515	499	488	476	455	417	375
Ph.D. and post docs	41	37	55	65	73	96	104	104	103
Students and trainees	51	48	51	47	46	44	41	36	29
Total staff	**974**	**914**	**940**	**956**	**964**	**971**	**960**	**899**	**863**

Green Account

Risø's Green Account has been a part of Risø's Annual Report since 1996.

The Green Account contains information on the consumption of resources such as water, electricity, heating, natural gas and coolants, as well as information on emissions into the environment in the form of atmospheric emissions, sewage, sewage sludge and waste. The impact on employees in the form of accidents at work and radiation doses is also included. The Green Account also includes documentation of Risø's ability to comply with legislation such as injunctions, etc. A new element is the inclusion of the number of fire alarms and fires/suspected fires.

Environmental statistics for Risø National Laboratory	Environmental key figures 1997	1998	Risø 1998	Limit or *typical values* [a]
Injunctions, etc.				
Injunctions from the environmental authorities	0	0		
Petitions from the environmental authorities	0	0		
Injunctions from the Labour Inspection Service	0	0		
Guidance from the Labour Inspection Service	2	4		
Instances of exceeding limit values for sewage	1	0		
Violations of 'Conditions for operating nuclear facilities'	0	4		
Special reports on the nuclear facilities	1	1		
Risks/Health and safety				
Accidents reported	18	16		
Injuries treated in Risø's emergency room [b]	78	58		
Industrial accidents reported to the Labour Inspection Service	3	6	7 per 1,000 [c]	*9 per 1,000* [d]
Industrial accidents reported to Occupational Injuries Agency [e]	1	1		
Fire alarms	33	17		
Fires/suspected fires	1	4		
Maximum individual effective dose [f] (mSv)	7.5	9.9	9.9 mSv	20 mSv [g]
Overall annual effective dose [h] (man-mSv)	167.6	159.3		
Consumption				
Water consumption (m^3)	59,276	69,839	75 m^3/PE	*62 m^3/PE* [i]
Power usage (MWh)	11,962	11,884	119 kWh/m^2 [j]	83 kWh/m^2 [k]
Heating (MWh)	12,776	12,465	185 kWh/m^2	190 kWh/m^2 [l]
Natural gas [m] (m^3)	1,862,998	1,733,257		
Coolants [n] (kg)	353	220		
Atmospheric emissions				
DR3: Argon (GBq)	23,400	24,500		
DR3: Tritium (GBq)	3,470	3,980	0.7 µSv/year [o]	200 µSv/year [p]
DR3: Iodine (GBq)	Negligible	Negligible		
Waste Management Plant: ^{14}C-emissions (GBq)	6	11		
Waste Management Plant: Particular ß activity (GBq)	Negligible	Negligible		
Sewage, etc.				
Sewage (m^3)	48,900	52,200	52,200 m^3	182,500 m^3 [q]
Chemical oxygen demand, COD (kg)	1,535	1,644	31.5 mg/l	
Biochemical oxygen demand, BI_5 (kg)	196	131	2.5 mg/l	15 mg/l
Suspended state (kg)	342	277	5.3 mg/l	20 mg/l
Total nitrogen (kg)	377	277	5.3 mg/l	6 mg/l
Total phosphorus (kg)	176	99	1.9 mg/l	
pH	8.0	8.0	8.0	6.5–8.5
Sediments (ml/l)	0.1	0.1	0.1 ml/l	0.5 ml/l [r]
Heavy metals [s] (kg)	9.5	7.2		
of which zinc (kg)	8.5	6.2	119 mg/l	1,000 µg/l
Tritium with distilled active sewage (GBq)	3,800	4,200		
Tritium in secondary cooling water from DR 3 (GBq)	33	99	3.3 kBq/ml	370 kBq/ml
Unspecified ß activity in treated sewage [t] (GBq)	0.064	0.077	0.0015 Bq/ml	0.15 Bq/ml
Sewage sludge				
Quantity of sludge (tonn)	6	6		
Heavy metals [u] (g)	14,500	14,000		
of which: Mercury (g)	61	29	5 mg/kg	0.8 mg/kg [v]
Cadmium (g)	31	51	9 mg/kg	0.8 mg/kg [v]
Nickel (g)	12 [w]	137	24 mg/kg	30 mg/kg [v]
Lead (g)	520	371	65 mg/kg	120 mg/kg [v]
Copper (g)	2,300	2,240	393 mg/kg	1,000 mg/kg [v]
Zinc (g)	5,570	5,790	1,016 mg/kg	4,000 mg/kg [v]
Uranium (g)	55	51	9 mg/kg	*2-10 mg/kg*
Waste				
Waste to be disposed of outside Risø (tonn)	166	164		
of which chemical waste [x] (tonn)	10	6		
Waste for recycling (tonn)	67	65		
Waste for disposal at Risø (tonn)	7	9		
Low-activity waste from Risø [y] (tonn)	3	3		
Low-activity waste from Danish customers [y] (tonn)	3	3		

Risø's impact levels are specified for 1997 and 1998. Limit values or typical reference values are specified so that Risø's levels can be evaluated in relation to these.

Risø has rectified all violations in 1997 and 1998. The offences had no serious consequenses for security, but have occasioned comments from the authorities about the safety culture at Risø.

The number of occupational accidents continues to fall, but a staff member was seriously injured by a traffic accident.

Risø has its own fire service and, in 1998, an assessment of fire risk at the nuclear facilities was undertaken. The final report on this work is expected to be completed during 1999. This year, the Green Account includes the number of fire alarms and fires/suspected fires. The four fires/suspected fires during 1998 did not give rise to serious injuries or financial losses.

Risø's operation of nuclear facilities makes it a unique institution in Denmark. As can be seen from the Green Account, the impact from this area is far below the permitted values. Collective radiation dose has continued to drop. Risø will continue the efforts to reduce the maximal individual radiation dose.

Risø continuously introduces energy conservation measures and the electricity consumption is now constant even though new plants have been brought into use that consume large quantities of energy. Calculated without the plants that consume particilarly large amounts of energy, electricity consumption related to the area is still higher than the comparative figure.

Risø's sewage treatment plant was reconstructed in 1996 to include the removal of nitrogen. In 1997, there were difficulties in complying with the regulations on nitrogen; Risø was just able to comply. In 1998, there has not been any great difficulty in complying with the regulations.

The concentrations of the heavy metals e.g. mercury and cadmium in Risø's sewage sludge still exceed the permitted levels for sludge to be spread on agricultural land. Risø's sludge is therefore not used for this purpose and is instead deposited at Risø's controlled disposal facility.

Viewed overall in 1998, Risø has reached the goals set for paper, computers and research instruments. Regarding computers, the goal was that 85% of computers purchased should comply with Risø's environmental specifications. 80% of the purchased computers complied with these environmental requirements.

The overall safety level at Risø is acceptable, but Risø is still working to improve the safety.

Risø's strategy is that safety is a natural part of everyday work. Action in the areas of the working environment and the external environment will be incorporated into the planning of Risø's work. In 1998, implementation began of changes in Risø's safety management. This means, among other things, that a new safety organisation has been set up with local safety committees and greater formal involvement of management at all levels. Changes in Risø's emergency preparedness organisation began in 1998, but it is anticipated that they will only be implemented to their full extent over a three-year period.

The effects of the changes include greater attention to safety at Risø. It is hoped that another effect of the changes will be better figures in Risø's Green Account in the future.

Notes

a Wherever Risø's endorsements specify limit values, these are noted. In some fields there are no limit values. As a comparison, as far as possible, limit values characteristic of equivalent areas/fields have been given in italics.
b The number of injuries, as in previous years, is calculated as all injuries treated by Risø's emergency room, i.e. it includes DMU, visitors and external tradesmen in addition to Risø's own employees.
c Per 1,000 man years.
d Per 1,000 employees in research and development in the areas of natural science and technology. For teaching and research as a whole: 10 accidents/1,000 employees. Source: *Reported industrial accidents, annual report 1996: National Institute of Occupational Health report no. 2*.
e The number of cases reported by Risø, i.e. cases reported by other parties (e.g. general practitioners/hospitals) are not included.
f Maximum individual effective dose: The individual effective dose is defined as the sum of the equivalent doses to each separate organ multiplied by its respective tissue weight factor. The maximum individual effective dose corresponds to the maximum dose to an individual employee.
g Radiation protection: Dose-limitation principles are applied in the area of radiation protection. These state that doses from exposure to radiation at work should be kept as low as reasonably achievable and that doses must not exceed the dose limits set by the government authorities.
h The collective dose of Risø's employees is defined as the sum of the individual doses received by all persons (effective doses).
i Roskilde Municipality's sewage plan, 1988.
j DR 3 and RERAF are not included in the electricity consumption figures by area, as this consumption is unique to Risø.
k Average electricity consumption by area for education and research. For offices, the electricity consumption is 57 kWh/m^2 (The Danish Energy Agency, 1997).
l Average heating consumption for education and research. For offices, the heating consumption is 109 kWh/m^2 (The Danish Energy Agency, 1997).
m Most of the natural gas was used to produce heat and electricity for Risø, DMU and the other institutions on Risø's grounds.
n Account of consumption of fully and partially halogenised hydrocarbons used for cooling purposes. In 1998, a total of approx. 100 kg of freon 12 and 100 kg of freon 22 was used.
o The doses from tritium, argon and iodine emissions are effective doses received by an imaginary person standing at Risø's perimeter fence in the same place all year round.
p The maximum contribution from each source is suggested by various government authorities as being between 100 and 300 µSv/year.
q The limit value is estimated from the amount of sewage discharge permitted per 24 hours under dry weather conditions.
r Guidelines for the amount of sediment after standing for two hours.
s The total content of the heavy metals for which Risø analyses its sewage. Analysis is performed for cadmium, lead, copper, uranium and zinc. (Heavy metals: Metals with a specific gravity in excess of 5 g/cm^3).
t Unspecified ß activity: Total activity for unspecified isotopes.
u The total content of heavy metals for which Risø analyses its sludge. Analysis is performed for chrome, nickel, copper, zinc, cadmium, mercury, lead, uranium, cobalt, arsenic, manganese, lanthanum, praseodymium and thorium.
v The limit values for the heavy metal content of sludge apply if the sludge is to be spread on land to be used for agricultural purposes. Risø's sludge is not currently used for this purpose, but is disposed of at Risø's controlled disposal facility.
w The low nickel content in 1997 is probably due to an analytical error.
x In recent years, chemical stocks at Risø have been cleared out. This explains why the quantity of chemicals sent to the municipal disposal facility for chemicals is still higher than normal.
y Low-activity waste deposited temporarily at Risø derives from Risø's own activities as well as including waste radioactive isotopes from the rest of Denmark which Risø is obliged to receive. Low-activity waste is defined by Risø as radioactive waste for which the dose rate at a distance of 1 m from the surface of the waste container does not exceed 5 mSv/h.

Collaboration partners

Industrial materials

Industry
A/S Hartfelt & Co.
Aerospatiale SA
Allied Signal Bremsbelag GmbH
Blankguss
Bombardier Talbot
Bonus Energy A/S
Bosch Systemes de Freinage
British Aerospace – Airbus
British Gas
Carl Bro A/S
CEDIP S.A.
CEIT de Guipuzcoa
Concargo/Polymer Engineering
CSM Materialteknik AB
Daimler Benz AG
Danish Steel Works Ltd.
DEMEX A/S
EA-Technology Ltd.
EM-Fiberglas, Hornsyld
English Welsh Scottish Railways
Fagor Ederlan, S. Coop. Ltd.
Ferriere e Fonderie di Dongo
Ferroperm
FIAT SpA
Fokker SP
Garrad Hassan & Partners, Ltd.
Gaz de France
German Aerospace Centre
GF Automobilguss
GIE Renault
Gränges AB
Gussstahl
Haldor Topsøe A/S
HB Consultancy
Hydro Aluminium a.s.
INTROSPACE GmbH
IRD A/S
J. B. Plant Fibres Ltd.
Kemijoki Yo
Magma
Metall-SpecialRohr GmbH
Mitsui Babcock Energy Ltd.
Morgan MT
NESA A/S
NKT Cables A/S
NKT Research Centre A/S
Nordtest
Norsk Hydro
Norsænk-Aalykke A/S
NST A/S
OTOBREDA
PBI-Dansensor A/S
Pechiney CRV SA
Photonic Science Ltd.
Plansee
Polymath
Ranshofen
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Roulunds A/S
Rover Group Ltd.
Sauerwein Systems Technik GmbH
Scan-Visan A/S
Schunk Kohlenstofftechnik
Sciotech
SEPARIS
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Sintech Keramik
Sistema Compositi
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Stampal SpA
Statoil a.s.
SVUM
TERMA Elektronik A/S
Thomsen Tubes Electroniques SA
Thürmer A/S
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TYK Corporation
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Volkswagen GmbH
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ILFB/TU Wien
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Katholieke Universiteit, Leuven
KU
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AAU

Research institutes, authorities, etc.
AEA Technology
Austrian Research Centre Seibersdorf GmbH
Bundesanstalt für Materialprüfung
CRRP
Danish Institute of Agricultural Sciences
DSM
DTI
ECN, Petten
EFPL
EFU GmbH
Elsamprojekt
EMPA
EN Santa Barbara
Force Institute
Frauenhofer
Hahn-Meitner Institut, Berlin
IMMG
Inst. of Physics and Power Engr., Obninsk
Institut de Soudure
Institute Laue Langevin
Institute National des Sciences Appliquées
Instituto de Soldadura e Qualidade
IPM. Riga
ISRIM
Joint Research Centre, Petten
National Physical Laboratory
National Research Institute for Metals
NFL (Studsvik)
NUVL
Oak Ridge National Laboratory
Pacific Northwest National Laboratory
Research Centre Jülich
Rutherford Appleton Laboratory
Sandia National Laboratory
Spav
Swedish Institute for Metal Research
Swedish National Testing and Research Institute
Swiss Federal Inst. for Materials Testing and Research
The Danish Agricultural Advisory Centre
The Danish Ministry of Environment and Energy
The Niels Bohr Institute
TNO-PML

New functional materials

Industry
Coloplast A/S
Danfoss
Grundfoss A/S
Haldor Topsøe A/S
JJ Xray
Lucent Technology
M & E A/S
Mallinckrodt Ltd
Medico Chemical lab. A/S
NEC – USA
NKT A/S
NOVO Nordisk A/S
Optilink A/S
Philips Ltd.
Radiometer A/S


MICHAEL FISCHER

Henrik Hauggard-Nielsen is a Ph.D. student in the Plant Biology and Biogeochemistry Department, where he works with stable isotopes to determine symbiotic nitrogen fixation in organically grown intercrops consisting of spring barley and field pea.


BOYE KOCH

Risø is developing new types of barley with less phytate. This considerably reduces the phosphorus content in pig slurry, reducing pollution of the environment from liquid manure. More phosphate and minerals like iron and zinc are available for human and animal nutrition. Pictured here is Ph.D. student Katja S. Johansen, Plant Biology and Biogeochemistry Department, working on protein purification.

Topsil A/S
Wolf & Kaaber A/S

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Chalmars
Cracow
DTU
Essen
ETH-Zurich
Gothenburg
Hamburg
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KVL
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Lund
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RUC (Roskilde University Centre)
Salford
Sheffield
Stuttgart
Warwick
Weizmann Institute
AAU

Research institutes
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ESRF, Grenoble
FOM Institute
Forschungszentrum, Karlsruhe
Hahn Meitner Institut, Berlin
Hasylab, Hamburg
ILL-Grenoble
INFM, Italy and BNC, Budapest
ISIS Oxford
KFA-Jülich
MPI, Berlin
MPI, Mainz
MPI, Stuttgart
NFL Studsvik Nyköping
Transuranium Institute, Karlsruhe
UMIST, Manchester
UNI-C Copenhagen

Optics and sensor systems

Industry
Alfa Romeo Avio, Societa Aeromotoristica per Aviazioni - Italy
Aprepa A/ British Aerospace Ltd. - UK
CEDIR SA - France
Cimel Electronics (CIMEL) - France
DanDisc A/ Dantec Measurement Technology A/S
DNP A/S
Giga A/S
Hamamatsu Photonics - Japan
Heat Transfer Tønder A/S
Heitronics Infrarot Messtechnik GmbH - Germany
Honeywell - Denmark and USA
Howden Laser - UK
Ibsen Micro Structures A/S
Intellix A/S
Ionas
JJ-X-Ray (CAT)
Kanitech A/S
NEG Micon
Nilpeter A/S
Nordic Laser Systems A/S - Denmark
PERA - UK
Raytek GmbH - Germany
Rea Tech (CAT)
Regstrup Vision
Rockwool A/S
Ruha A/S
Sensor Partners (SPS) - the Netherlands
SK-energi I/S
Stensborg (CAT)
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Torsana A/S
Unisensor
Vestforbrænding I/S - Denmark
VIDROPOL - Portugal
WEA Engineering (CAT)
Aalborg Sunrod

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Birmingham - UK
Brown University - USA
Canterbury at Kent - UK
Chernivtsy University - Ukraine
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Eindhoven University of Technology - the Netherlands
Erlangen - Germany
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Konstanz - Germany
Crakow - Poland
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New Mexico - USA
Oslo - Norway
Osnabrück - Germany
Pisa - Italy
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Trinity College - Ireland
Tromsø - Norway
Universidad Autónoma de Madrid - Spain
Virginia - USA
AAU

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Copenhagen Hospital, Herlev/University of Copenhagen
Danish Institute of Agricultural Sciences
Deutsche Zentrum für Luft- und Raumfahrt - Germany
EURATOM
FOA - Sweden
Gesellschaft für Mathematik und Datenverarbeitung - Germany
Institute for Automation and Electrometry, Novosibirsk - Russia
Institute for High-Performance Computer Systems - Russia
Institute for Metal Physics, Ekaterinburg - Russia
Institute for Problems in Mechanics, Moscow - Russia
Institute of Crystallography of RAS, Moscow - Russia
IPP Garching - Germany
KFKI Research Institute - Hungary
Kurchatov Institute - Russia
L.D. Landau Institute - Russia
Marselisborg Hospital/ University of Aarhus
Nasa Lewis Research Center - USA
NPL Management Ltd. - UK
Racah Institute of Physics - Israel
UNI-C
USAF Academy – USA
Vavilov Institute, St. Petersborg - Russia
Worcester Polytechnic Institute - USA

Plant production and ecology

Industry
Abedfonden
AFEAS (The association of freon manufacturers)
Biocrack A/S
Bioscan A/S
Carlsberg Laboratory
Condea Agusta and Petrea (the LAS industry, Italy and Spain)


BOYE KOCH

Mass spectrometer with nanospray ionisation. This technique provides a particularly high degree of sensitivity and is used especially in studies of biomolecules, for example peptides. The mass spectrometer used is capable of extensive characterisation of the individual compounds, for example in amino acid sequence determination. Pictured here is post doc Christian Schou.


BOYE KOCH

Nils Berg Madsen, an industrial post doc at Novo, is working on polymer synthesis. At Risø, structure characterisation and modelling are combined with design, synthesis and function testing. The objective is to develop new molecules with the exact characteristics that are desired.

Danisco Seeds
DLF-Trifolium A/S
Dronningborg Industries A/S
EURIMA
FLS A/S
Ford Motor Company
KEMIRA
Kemp & Lauritzen
Knud Jepsen a/s
The Danish Agricultural Advisory Centre
Nordisk Jern & Metal A/S
Norsk Hydro
Novo Nordisk Fonden
Pajbjergfonden
PLM Langeskov
Rockwool International A/S
Sejet Plant Breeding
Danish Meat Research Institute
Topsil A/S
Unizymes A/S
Vand & Miljø A/S
Vølund/Ansaldo

Government research institutions, etc.
Danish Institute of Agricultural Sciences
DMU
DTI
DTU
Force Institute

Authorities, etc.
National Forest and Nature Agency
Danish Directorate for Development

Universities, etc.
AU
GEOMAR (Kiel)
GEUS
GSF (the geological survey of Finland)
ICARDA
INRA Grignon – France
IOW (Warnemünde)
IVL (Sweden)
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KVL
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Roskilde University Centre
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University of Adelaide, Australia
University of Lund
University of North Carolina
University of Stockholm
University of Vilnius
VTT (Finland)
AAU

Systems analysis

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CAT
CERC
Daimler Benz Aerospace
Danfoss
Danisco Ingredients
Association of Danish Electric Utilities
Danske Slagterier
DANTEC-MT
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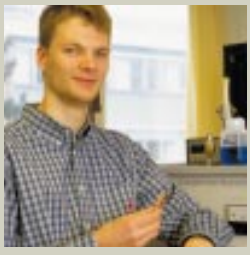
Cape Town
Chalmers
DTU
Free University of Amsterdam
KU
KVL
Laforia – Paris
Lund
Maastricht
Oulu
Portsmouth
RUC
School of Economics and Business Administration, Stockholm
Sheffield
Stuttgart
Surrey
Sussex
Technical University of Budapest
Technical University of Delft
University of Gothenburg
Washington (Seattle)
York University
AAU

Research institutes
AIT
AKF
CEA
CEETA
CIEMAT
CIRED
The Danish Maritime Institute (DMI)
Defence Evaluation and Research Agency
DEFU
Demokritos
DFH
DMU
Danish Institute of Plant and Soil Science
Norwegian Defence Research Establishment
Fraunhofer Institut
INERIS
JRC Ispra
Lawrence Berkeley National Laboratory
Max Planck Institut für Plasmaphysik
NUTEK
OECD Halden Reactor Project
RIVM
SEI
SJFI
SNF (Danish Natural Science Research Council)
TNO
UNAM
VITO
VTT
National GOs and NGOs
AFREPREN
Ammunitionsarsenalet (Ammunitions arsenal)
Labour Inspectorate
Ministry of the Interior's Emergency Management Agency
CEEST
Danced
Danida
Statistics Denmark
DØRS
ENDA
ENEA
ENER Network
Danish Energy Agency
EORTC
ETCW
EU
EUROCONTROL
FCC Secretariat
Fredericia Municipality
GEF
GTZ
HSE


MICHAEL FISCHER

Thomas Nikolajsen is a Ph.D. student in the Optics and Fluid Dynamics Department, where he is working on a new type of photorefractive crystal with a view to application in the area of holographic data storage.


MICHAEL FISCHER

Henrik Rønnow is a Ph.D. student in the Condensed Matter Physics and Chemistry Department, where he is working on quantum magnetism in low-dimensional model systems.

IDEE
IEA
IGIDR
Institut Gustave Roussy
Karolinska Sjukhuset (Hospital)
KAS (Copenhagen County Hospital) Gentofte
Kennedy Institute of Rheumatology
Kite
Office of Hospital Emergency Planning
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NILU
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Rädningsverket
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Statens Kärnkraftinspektion
Danish Aviation Authority
Danish Serum Institute
The Central Bureau of Statistics (Norway)
Södermansland Län
The World Bank
UNDP
UNEP
University Hospital of Rotterdam
US-CSP
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WEC
WRC

Wind energy and atmospheric processes

Collaboration partners

Private companies

ABB
Bonus Energi
Carl Bro
COWIconsult
CRES, Greece
Dahl Instrumenter
Danservice
DNV (Det Norske Veritas)
E&M Data
Elkraft
Elsam
Elsamprojektet
Energy and Environmental Data
EPP (Greek electricity utility)
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Hanstholm Møller
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SEAS
Siemens
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Wind World
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Ministry of the Interior's Emergency Management Agency
CENELEC
CIEMAT
Danida
Danish Standards Institute
DEFU
DMI
DMU
DTI
Egyptian Meteorological Authority
ENEL, Italy
Danish Energy Agency
EPRI
Eurec Agency
EWEA
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IEC
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The World Bank

Nuclear safety

Collaboration partners

Private companies
Elsamprojekt A/S
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NFI, Sweden
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RECOM Ltd, Russia
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Studsvik AB, Sweden
Wheelaborator Environmental Systems, USA

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Federal Radiological Centre, St. Petersburg, Russia
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The Danish Institute of Radiation Hygiene
STUK, Finland
SURREC, East Kilbride, Scotland
TNO, The Netherlands
VTT, Finland

BOYE KOCH

Tensile strength measurement of plant fibre composites is an important element in the work to utilise eco-friendly plant fibres in advanced construction materials. Pictured here is research technician Frank Adrian.

Acronyms and abbreviations

AFREPREN: The African Energy Policy Research Network

AIT: Asian Institute of Technology

AKF: Institute of Local Government Studies – Denmark

ARTMUS: Artificial muscles

ATV: The Danish Academy of Technical Sciences

BRITE: Basic Research in Industrial Technology for Europe

CANTOR: Converging Agreement by Networking Telematics for Object Recognition

CAT: Centre for Advanced Technology. Science park established jointly by Risø, RUC and DTU.

CEA: Commissariat à l'Energie Atomique

CEEST: Centre for Energy, Environment, Science and Technology

CENELEC: European Committee for Electrotechnical Standardisation

CIEMAT: Centro de Investigaciones Energéticas Medioambientales y Technológicas

CIRED: Centre international de recherche sur l'environnement et le développement

CO_2: Carbon dioxide. A gas produced by burning fossil fuels. CO_2 belongs to the group of gases contributing to the greenhouse effect.

DANAK: Danish Accreditation

DEFU: The research institute of the Danish electrical utilities

DFH: The Royal Danish School of Pharmacy

DMI: The Danish Meteorological Institute

DMI: The Danish Maritime Institute

DMU: The National Environmental Research Institute

DNA: Dioxyribonucleic acid

DNV: Det Norske Veritas

DR3: Risø's DR3 research reactor

DTI: The Danish Technological Institute

DTU: The Technical University of Denmark

DØRS: The Secretariat of the Danish Economic Council

EFP: The energy research programme of the Danish Ministry of Environment and Energy

ENDA: Environmental Development Action in the Third World

ENEA: Ente per le Nuove tecnologie, l'Energia e l'Ambiente

ENER Network: The European Network for Energy Economics Research

EORTC: European Organisation of Research and Treatment of Cancer

EPFL: Ecole Polytechnique Fédérale de Lausanne

ESRF: European Synchrotron Radiation Facility

ETCW: European Topic Centre on Waste

EURAM: European Research in Advanced Materials

EURATOM: European Atomic Energy Community

EUREC-Agency: European Renewable Energy Centres – Agency

EUREKA: European Research Co-ordination Agency

EUROCONTROL: European Organisation for the Safety of Air Navigation

EWEA: European Wind Energy Association

FCC Secretariat: Framework Convention on Climate Change

GEF: The World Bank's Global Environmental Facility

GTZ: Deutsche Gesellschaft für Technische Zusammenarbeit. A German support programme to implement the UNFCCC.

HSE: Health and Safety Executive

IDEE: Instituto de Economía Energética a la Fundación Bariloche Argentina

IEA: The International Energy Agency

IEC: International Electrotechnical Committee

IGIDR: Indira Gandhi Institute of Development Research

INTAS: International Association for the Promotion of Co-operation with Scientists from the New Independent States of the former Soviet Union

IPCC: Intergovernmental Panel on Climate Change

ITER: International Thermonuclear Experimental Reactor

JOULE: Joint Opportunities for Unconventional or Long-term Energy Supply

KU: The University of Copenhagen

KVL: The Royal Veterinary and Agricultural University

LIFE: Financial Instrument for the Environment, EU

MATE: Multi-Aircraft Training Environment

MIC: Mikroelektronik Centret

MP2M: Materials Processing, Properties and Modelling

MUP: The Danish Materials Technology Programme

MW: Megawatt. 1 million watts.

NILU: Norwegian Institute for Air Research

NKS: Nordic Nuclear Safety Research. A Nordic committee with participants from government authorities, research institutes and companies involved in nuclear power.

NKT: NKT Cables A/S

NUTEK: Swedish National Board for Industrial and Technical Development

OLADE: La Organización Latinoamericana de Energía

OU: Odense University

RERAF: Risø's Environmental Risk Assessment Facility

RIVM: Rijksinstituut voor Volksgezondheid en Milieuhygiëne

RUC: Roskilde University Centre

SCEE: Southern Centre for Energy and Environment, Zimbabwe

SEI: Stockholm Environment Institute

Sida: Swedish International Development Co-operation Agency

SINTEF: The Foundation of Scientific and Industrial Research at the Norwegian Institute of Technology

SJFI: Danish Institute of Agricultural and Fisheries Economics

SNF: The Danish Natural Science Research Council

SOFC: Solid oxide fuel cell. Fuel cells made of ceramic materials.

THERMIE: Technologies Européennes pour la Maîtrise de l'Energie

THOR: Technology by Highly Oriented Research. The Ministry of Research and Information Technology's new THOR programme.

TMR: Training and Mobility of Researchers

TNO: Nederlanse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek

TNO-PML: Nederlanse Organisatie Voor Toegepast Natuurwetenschappelijk Onderzoek. Netherlands Organization for Applied Scientific Research

UCLA: University of California, Los Angeles

UNAM: Universidad Nacional Autónoma de México

UNDP: United Nations Development Programme

UNEP: United Nations Environment Programme

US-CSP: US Country Studies Program

VITO: Vlaamse Instelling voor Technologisch Onderzoek

VIT: Valtion Teknillinen Tutkimuskeskus, Finland

WAsP: Wind Atlas Analysis and Application Program, developed at Risø.

WEC: World Energy Council

WRC: Water Research Centre

AAU: Aalborg Universitet

BOYE KOCH

Medicine capsule material surfaces are being studied in collaboration with Novo Nordisk A/S. This work has led to a number of patent applications. Pictured here from left to right are industrial post doc Nils Berg Madsen of Novo and technician Lene Hubert.

Back-cover illustration: Testing of fatigue strength of glassfibre reinforced composites is an important way to document the usefulness of composite materials for rotor blades on wind turbines. For the exploitation of wind energy in cold and arctic regions testing is performed at temperatures of -30°C. Photo: Boye Koch

Risø National Laboratory carries out scientific and technological research in order to create new technological development. The results of Risø's research are used by Danish and international industry, governmental bodies and international organisations. Risø contributes to education of scientists through Ph.D. and post-doctoral programmes.

Risø reports its activities in 1998 in the following publications: Risø Annual Report (available in Danish and English), Annual Performance Report (only available in Danish), Risø's Publication Activities and the annual progress reports of the seven research departments. The publications and further information about Risø can be obtained from the web site www.risoe.dk. Printed copies of the reports are available from the Information Service Department, tel. +45 4677 4004, email risoe@risoe.dk, fax +45 4677 4013.

Risø National Laboratory
April 1999
Risø-R-1095(EN)

Editor: Leif Sønderberg Petersen
Secretary: Inge Ilsøe
Design: Grafikerne 98331-29
Print: Holbæk Center Tryk A/S
Translation: Interpen Translation A/S

ISBN 87-550-2499-8
ISBN 87-550-2500-5 (Internet)
ISSN 0106-2840
ISSN 0908-729X